APPENDIX B

Devils Lake, North Dakota

Final
Integrated Planning Report
And
Environmental Impact Statement

Economic Evaluations

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APPENDIX B - ECONOMICS

1. INTRODUCTION

This appendix summarizes the work done under contract by Barr Engineering to evaluate the economic feasibility of a range of alternatives for reducing the flood threat at Devils Lake. Many alternatives have been considered ranging from storage of runoff in the upper basin to outlets that would drain lake water to the Sheyenne River to levees that would protect selected roads and areas landward of the roads. Details of this analysis are available in Barr's report entitled, Economic Analysis of Devils Lake Alternatives (Technical Appendix, November 2001 and Tabular Data, December 2001).

The general methodology for evaluating benefits followed the traditional stochastic approach as directed by Corps of Engineers planning guidelines. This type of an analysis is based on the probability of hydrologic events and the resulting damages and project benefits that ensue. Due to the uncertainty associated with projecting future lake levels, however, several alternate future climatic scenarios were also considered. These provide a different perspective on the potential for future flood damages under the without-project condition and benefits for any alternatives under consideration. The scenarios evaluated included a wet future, two moderate futures, and a dry future.

2. METHODOLOGICAL APPROACH

2.1 Stochastic Analysis

The stochastic analysis evaluates future damages and benefits based on a large set of possible future lake levels – 10,000 traces. A trace is a year-by-year projection of lake level and has a length of 50 years. The large number of traces was generated as a way of dealing with the uncertainty regarding future lake levels. Because the calculations of costs and benefits for any alternative depend on the prediction of lake levels, any cost and benefit calculations can be no more reliable than the lake level predictions. The stochastic analysis provides a large number of lake level predictions varying according to fluctuations within reasonable expectations regarding future weather patterns. Damages are evaluated on a yearly basis by integrating the lake elevation from the trace for that year with the elevation-damage relationships for the many features around the lake. Future damages are then discounted to present value and then amortized over the 50-year planning period to derive its average annual equivalent value. By computing an alternative's benefits and costs for each of the 10,000 traces, and then averaging these benefits and costs, a reasonable expectation of the costs and benefits for the alternative can be determined.

For the stochastic analysis, every set of 10,000 without-project traces has a companion set of 10,000 with-project traces. Because each trace reflects a unique 50-year projected climate future, each of the 10,000 50-year traces for each alternative is different.

The first 15 years of the stochastic traces were generated based on the assumption that climatic conditions would be similar to those experienced during 1980-1999, reflecting the generally wetter conditions that the Devils Lake Basin has been experiencing since 1980. For the modeling, these conditions were assumed to persist until at least 2015. After 2015, the simulation model assumes that climatic conditions can be represented by the longer historic period 1950-1999. The average peak lake level resulting from the stochastic analysis was 1451.7 and the median was 1450.1.

2.2 Wet Future Scenario

The wet future scenario analysis uses only one trace of 50-year lake levels that is based on recent climatic conditions. It is not necessarily an extreme scenario, but it is intended to reflect a future condition that is comparable to the very recent history of wet conditions. The wet future scenario repeats the climatic and hydrologic conditions for the seven highest inflow years in recent history (1993-1999) for three cycles (21 years) causing the lake to overflow. The remaining years of the 50-year trace were defined assuming climatic and hydrologic conditions similar to 1980-1999.

The Wet Future trace rises gradually for about 14 years until the natural overflow occurs in year 2014. The lake remains above the natural outlet elevation for about another 11 years. The peak lake level for the scenario occurs in year 19 at an elevation of 1460.6. There is a second peak that occurs near the end of the 50-year period; however, it has a lower peak flood level than the first peak and no additional overflow occurs. By comparison, this wet future is representative of approximately 10 percent of the stochastic traces, representing those traces that have an average peak lake level of 1461.1.

3. FEATURES AND DAMAGE TYPES

For purposes of damage analysis around Devils Lake, 24 features have been identified as entities subject to damage if the lake continues to rise. Most of these features can be protected either by raising them (roads, railroads), relocating them (communities, rural residences), or by building a levee to protect the area from encroaching lake waters. These features have been protected in the past and are likely to be protected to some degree in the future. A list of these features appears in the following table.

Table B-1 - Features Adjacent to Lake

Communities and Cities		**Roads**	
1	Church's Ferry	13	US Hwy 2
2	City of Devils Lake	14	Hwy 57 between Hwy 20 and BIA 1
3	Fort Totten	15	Hwy 57 between BIA 1 and Hwy 281
4	City of Minnewauken	16	Hwy 281 south of US Hwy 2
5	St. Michael	17	Hwy 281 north of US Hwy 2
State Facilities		18	Hwy 19 from DL levee to Hwy 281
6	Grafton State Military Reservation	19	Hwy 1
7	Graham's Island State Park	20	Hwy 20 north of City of Devils Lake
Rural Areas		21	Hwy 20 from DL levee to Hwy 57
8.1	Devils lake Rural Areas	22	Hwy 20 between Hwy 57 and Tokio
8.2	Stump Lake Rural Areas	23	BIA 1 between Hwy 57 and BIA 6
Rail Lines		24	BIA 6 between Hwy 20 and Fort Totten
9	Red River Valley and Western RR		
10	CPRR: City of Devils Lake - Harlowe		
11	BNRR along US Hwy 2		
12	BNRR: Church's Ferry - Cando		

The type of feature dictates the type of damage it incurs and involves a different method for calculating damages. There are three categories of potential flood damages for features adjacent to the lake. These are:

- continuously occurring damages - an example of these are detours for vehicles caused by closed roads or recreation losses caused by closed recreation facilities.
- one-time only damages – these damages occur only once over the 50-year trace of lake elevations and include, as examples, structures and land.
- once-per-event damages – these will occur each time the lake rises and falls and include, for example, roads that have to be repaired when the lake recedes sufficiently.

These damages all increase as the lake level rises. The continuously occurring damages (detour, trucking, and lost recreational use damages) total over $79 million at the maximum lake level (see Table B-2). The one-time-only damages to land and infrastructure total $519 million at the maximum lake level (see Table B-3). The allocation of the one-time-only damages is shown on Figure B-1. The once-per-event restoration damages to roads and rail lines total just over $131 million at the maximum lake level (see Table B-4).

Similar to the evaluation of the damages prevented by the alternative, a reconnaissance-level investigation was completed to define the costs avoided under the with-project condition. These cost savings are a result of reduced flood protection measures within the basin because the project has lowered the lake level.

Figure B-1
Land and Infrastructure Damages
at Maximum Lake Level

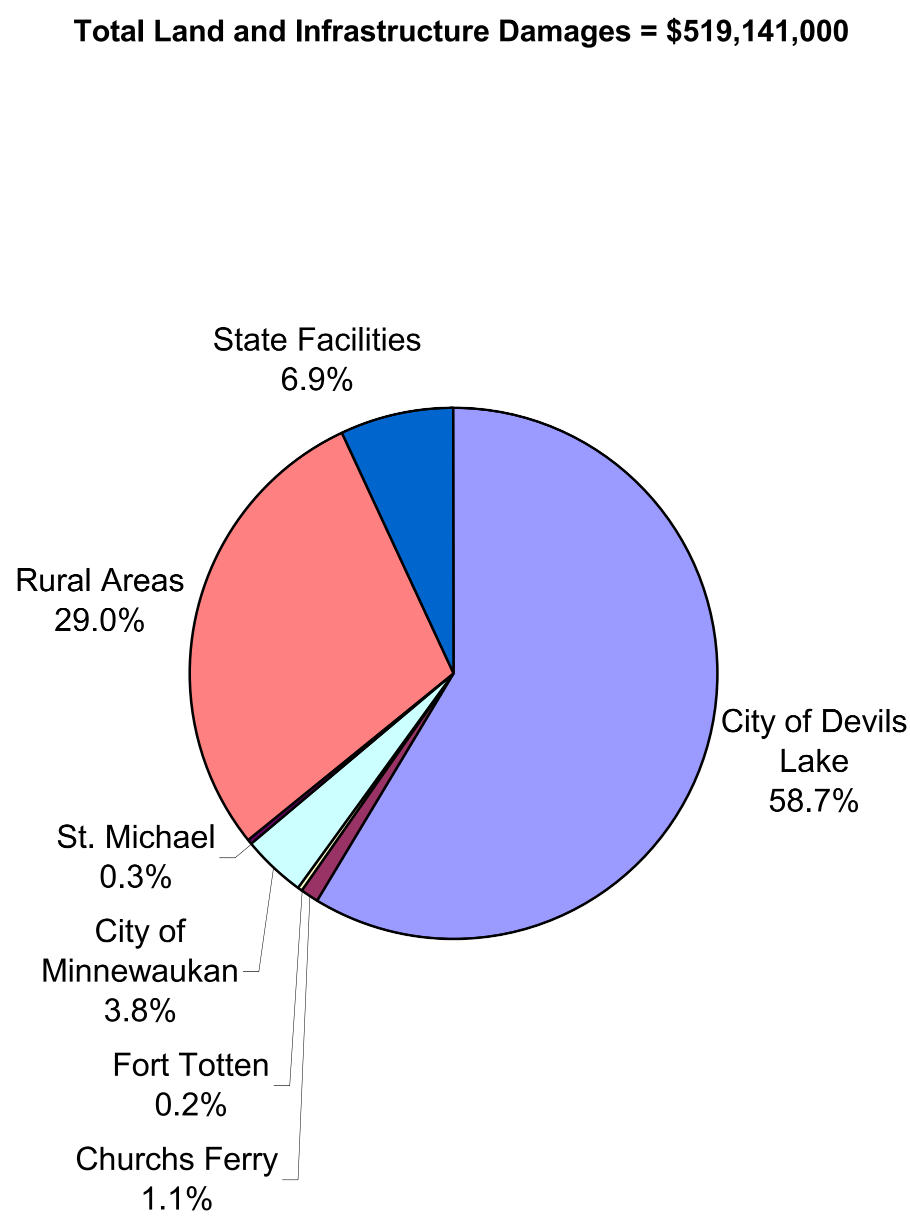


Table B-2 - Cumulative Annual Damages (Assuming temporary closure - damage x $1,000)				
Lake Elevation	State Facilities Lost Recreation	Rail Lines Detour Costs	Roads Detour Costs	Total
1440	0	0	0	0
1441	0	0	0	0
1442	0	0	0	0
1443	0	0	13,073	13,073
1444	0	0	13,073	13,073
1445	0	0	13,073	13,073
1446	0	0	13,649	13,649
1447	516	0	18,863	19,379
1448	516	0	18,863	19,379
1449	516	509	19,818	20,843
1450	516	509	19,818	20,843
1451	516	509	21,140	22,165
1452	516	4,650	21,140	26,306
1453	516	4,650	21,140	26,306
1454	516	5,159	70,021	75,696
1455	516	5,159	70,021	75,696
1456	516	5,159	70,021	75,696
1457	516	5,159	70,021	75,696
1458	516	5,159	70,021	75,696
1459	516	5,159	73,396	79,071
1460	516	5,159	73,396	79,071
1461	516	5,159	73,396	79,071
1462	516	5,159	73,396	79,071
1463	516	5,159	73,396	79,071

Table B-3 - Cumulative Land and Structural Damages (assumes no protection - damage x $1,000)				
	Cumulative Land and Structural Damages			
Lake Elevation	Communities and Cities	Rural Areas	State Facilities	Total
1440	0	2,841	0	2,841
1441	0	2,841	0	2,841
1442	0	2,841	0	2,841
1443	0	2,841	0	2,841
1444	0	4,512	0	4,512
1445	0	4,512	0	4,512
1446	0	4,512	0	4,512
1447	5,535	23,186	335	29,056
1448	5,535	35,109	335	40,979
1449	182,794	38,426	609	221,829
1450	187,853	46,150	609	234,612
1451	188,163	52,871	674	241,708
1452	238,625	55,391	674	294,690
1453	238,625	66,295	674	305,594
1454	254,724	75,506	685	330,915
1455	255,220	78,104	685	334,009
1456	332,879	96,180	771	429,830
1457	332,879	96,180	771	429,830
1458	332,879	115,565	771	449,215
1459	332,879	116,485	771	450,135
1460	332,879	150,649	771	484,299
1461	332,879	150,649	35,613	519,141
1462	332,879	150,649	35,613	519,141
1463	332,879	150,649	35,613	519,141

Table B-4 - Road and Rail Line Restoration Damages (Assume no protection - damage x $1,000)			
Lake Elevation	Rail Line	Roads	Total
1440	0	0	0
1441	0	0	0
1442	0	0	0
1443	0	0	0
1444	0	31	31
1445	0	31	31
1446	0	31	31
1447	0	6,867	6,867
1448	0	9,434	9,434
1449	0	9,434	9,434
1450	4,963	10,176	15,139
1451	4,963	15,484	20,447
1452	4,963	20,184	25,147
1453	7,860	20,959	28,819
1454	9,517	23,655	33,172
1455	13,238	46,420	59,658
1456	14,444	49,188	63,632
1457	16,790	61,475	78,265
1458	20,328	64,701	85,029
1459	22,007	69,714	91,721
1460	24,383	75,897	100,280
1461	31,158	82,635	113,793
1462	34,431	88,142	122,573
1463	39,924	90,911	130,835

4. WITHOUT-PROJECT CONDITION

The without-project condition assumes that actions taken in the past to reduce damage from the rising lake will continue in the future. This is referred to as the most-likely strategy in terms of protection of the features around Devils Lake. No established plan exists for protecting features as the lake rises. Protection is provided on an as-needed basis by a variety of governmental agencies. Each feature will have a unique strategy for flood protection as the lake level rises. This strategy is implemented for each feature on an incremental basis and is intended to provide protection in roughly 5-foot intervals. Because no established overall plan exists, the most-likely feature protection strategy has been developed based on past protection actions and on the judgment of local officials with prior experience in dealing with the flooding problem. Depending on feature type, actions may include levee raises, road raises, structure relocations, or a combination of these. In some cases, where protection is not reasonable, such as for cropland or for low-traffic roads, no action is taken to prevent flood damage. This set of *most likely actions* was assumed to be the without-project condition for most alternatives evaluated in this study, meeting the National Economic Development (NED) criteria as "the most likely condition expected to exist in the future in the absence of a proposed water resources project." Table B-5 presents the feature protection costs by lake elevation used for this analysis.

It is important to note that the assumption of *most likely actions* regarding local flood protection measures is only made for the purposes of computing NED benefits, and is not a proposed plan of action or a prediction of what local officials may actually implement. Other strategies may actually be implemented for a particular feature because of funding limitations, for environmental or social reasons, or if the lake rises faster than measures can be implemented.

For each feature, the analysis evaluated a wide range of strategies for both the with-project and without-project conditions. The costs to implement each strategy and the associated damages were expressed as a function of lake level and used as input to the economic modeling program (Features Analysis Model). For each 50-year trace of lake levels, the model accounted for the appropriate flood protection costs and associated damages at each feature. For each trace, the 50 years of costs and damages were then converted to a present worth value and an average annual cost or damage. The analysis computes the annual costs and damages for that trace for the most likely strategies. This process was repeated under both the with-project and without-project conditions.

For the stochastic analysis, this process was repeated 10,000 times for the most likely action strategy to evaluate the full range of possible 50-year futures without a project. The average of the 10,000 average annual values produced from these traces represents

Table B-5 - Feature Protection Costs by Elevation

Feature Number	Feature	Strategy	1447	1448	1449	1450	1451	1452	1453	1454	1455	1456	1457	1458	1459	1460	1461
1	Church's Ferry	s2	5,314								277						
2	City of Devils Lake	l3			9,595			46,476					25,371				
3	Fort Totten	s3	68				340					544					
4	City of Minnewaukan	l2				5,349					2,453						
5	St. Michael	s3	159			68					1,632						
6	Grafton State Military Reservation	r4	3,151				3,124					5,958					12,993
7	Graham's Island State Park	r4	56		3,713					2,229		5,704					6,300
8	Devils lake Rural Areas	s11	11,832		2,040	1,360		1,972	2,652		2,108	4,420		4,148		7,888	
8	Stump Lake Rural Areas	s1			363												
9	Red River Valley and Western RR	NA															
10	CPRR: City of Devils Lake - Harlowe	r3			24,597					25,009					41,540		
11	BNRR along US Hwy 2	r2								16,452					47,427		
12	BNRR: Church's Ferry - Cando	r2								16,561					52,833		
13	US Hwy 2	r2								50,648					102,090		
14	Hwy 57 between Hwy 20 and BIA 1	r2								6,203					8,071		
15	Hwy 57 between BIA 1 and Hwy 281	r2								16,380					26,287		
16	Hwy 281 south of US Hwy 2	r5	3,829	37,471					43,464					52,807			
17	Hwy 281 north of US Hwy 2	r3					12,126					23,537					38,376
18	Hwy 19 from DL levee to Hwy 281	r2								38,810					62,442		
19	Hwy 1	Already relocated															
20	Hwy 20 north of City of Devils Lake	r1													33,382		
21	Hwy 20 from DL levee to Hwy 57	r2								10,803					14,056		
22	Hwy 20 between Hwy 57 and Tokio	r4	5,119				4,607					26,814					36,194
23	BIA 1 between Hwy 57 and BIA 6	r3			5,119					4,607					8,704		
24	BIA 6 between Hwy 20 and Fort Totten	r5		1,664					5,065					6,568			
	Subtotal		29,528	39,135	45,427	6,777	20,197	48,448	51,181	187,702	6,470	66,977	25,371	63,523	396,832	7,888	93,863
	Cumulative Total		29,528	68,663	114,090	120,867	141,064	189,512	240,693	428,395	434,865	501,842	527,213	590,736	987,568	995,456	1,089,319
	Strategy: s = structure relocation; l = levee raise; r = road raise; # = number of times action is implemented.																

the (overall) average annual value for costs and damages for the without-project condition. To provide comparable data for the with-project condition, the entire analysis of the most likely action strategy was then repeated using the 10,000 with-project traces. The average of the 10,000 average annual values produced from these traces represents the (overall) average annual values for costs and damages for the with-project condition.

5. DOWNSTREAM IMPACTS

The without-project condition downstream along the Sheyenne and Red Rivers must be established in order to develop a baseline against which effects of an outlet can be evaluated. The without project condition includes the potential for overflows through the natural outlet along Tolna Coulee if the lake reaches an elevation of approximately 1460. With-project impacts of an outlet may include flooding of cropland, other agricultural property, urban areas, and transportation infrastructure; increased costs to municipalities and industrial users to treat potentially degraded water supply; and impacts to agricultural producers that rely on the river as a source of irrigation water.

Inputs required for this analysis include projections of the downstream flow rates and water quality to allow assessment of the benefits of any alternative that results in outflow from Devils Lake. The 50-year traces of downstream river characteristics were generated through use of a lake model that tracks water quality in each of six bays of Devils Lake, using trace data from the lake level model described above as input. Tracking the water quality of the six bays allows determination of the water quality of a discharge from any bay of the lake. The discharge rate is determined based on the pumping rate allowed for a pumped outlet or on the lake level in the case of either a gravity outlet or an overflow at the natural outlet. Projections of discharge water quality and quantity from the lake are integrated with projections for the Sheyenne River and the Red River of the North; the projections are based on the same weather conditions assumed for generating the lake level model's trace data.

For the stochastic analysis, evaluation of downstream river characteristics using sets of 10,000 traces was not feasible for the downstream features. Instead, the downstream features analysis was evaluated for a representative set of four downstream river traces. The four representative traces each correspond to one of four categories of the 10,000 traces—a Wet Future, two Moderate Futures, and a Dry Future—and each trace represents a certain percentage of the 10,000 traces (see Table B-6 below). Using the four traces, therefore, costs and benefits (whether positive or negative) could be determined for each and a weighted average for the downstream features could be determined for each alternative.

Table B-6 - Categories of Traces for Evaluating Impacts of Alternatives

Scenario	Peak Lake Level 2001 - 2050 With No Outlet	Percent of Traces (out of 10,000)	Average Peak Lake Level
Dry	1,447.0 to 1,449.0	35.6	1,448.10
Moderate 1	1,449.1 to 1,452.0	29.9	1,450.20
Moderate 2	1,452.1 to 1,459.0	25.0	1,454.90
Wet	1,459.1 to 1,465.0	9.5	1,461.10

As with the portion of the economic analysis based on the evaluation of the set of 10,000 lake level traces, each downstream with-project trace must be compared to a corresponding without-project trace to determine the benefits of the alternative.

For the analysis of the wet future scenario, downstream river characteristics were evaluated directly for each alternative, based on the 50-year trace of downstream water quality and quantity. Again, each downstream with-project trace must be compared to a corresponding without-project trace to determine the benefits of the alternative.

Downstream features may be affected by either changes in water quality or changes in flow volumes resulting from an outlet alternative. Downstream features affected by changes in water quality include municipal water treatment facilities (MWTF's), industrial facilities, and irrigators.

5.1 Water Quality Effects

The municipal water treatment facilities included in this analysis are at Valley City, Fargo, Grand Forks, Grafton, Drayton, Pembina, Letelier, and Morris. If the without-project condition does not include an overflow from Devils Lake, then the with-project condition (i.e., outlet) will likely make downstream water quality conditions worse. Damage occurs due to higher costs of water treatment to remove dissolved solids. Methods for dealing with reduced water quality range from additional softening for moderate problems to acquiring an alternate water supply source or employing an ion exchange treatment alternative for more severe cases. The severe cases are more likely to occur during a major overflow scenario or if a 480-cfs unconstrained outlet is implemented. However, if the without-project condition does include an overflow, as under the wet scenario or for a “wet” stochastic trace, it is possible that the outlet condition may be an improvement over the without-project condition and benefits in the form of lower treatment costs may result.

Of the several industrial facilities along the Sheyenne River and the Red River, those that would be adversely affected by changes in water quality include a sugar beet processing plant and a coal-fired power plant, both located on the Red River. As with the MWTF’s, damages or benefits resulting from operation of an outlet are calculated as the change in treatment costs when compared with the without-project condition. These facilities were interviewed to collect information about their operations, how changes in water quality affect their operations, and what these effects mean in economic terms.

Irrigators are the third category of downstream water users affected by changes in water quality. Depending on their expectations and propensity for risk-taking, irrigators’ response to reductions in water quality may vary from no change in operation to continuing to irrigate but shifting to a more salt-tolerant crop to avoiding irrigation altogether. For this study, it was assumed that all irrigators of salt-sensitive crops would avoid irrigating until levels of total dissolved solids (TDS) dropped below a certain threshold. The economic effect is a reduction in yields and the lost income is considered a damage resulting from the reduction in water quality. County officials and a sample of irrigators were interviewed to obtain the necessary data for this analysis.

5.2 Flood Damage Effects

Downstream features affected by changes in flow volumes include cropland, other agricultural property, transportation infrastructure, and urban property. Data taken from prior studies on the Sheyenne River and Red River serve as the basis for the downstream flood damage analysis. For purposes of analysis, the downstream impact area for the flood damage analysis is divided into reaches as indicated in Table B-7. Because the Red River of the North carries so much more water than the Sheyenne River, it was assumed that any additional flow form Devils Lake would be insignificant; flood damage on the Red River of the North would not be significantly increased by the addition of Devils Lake flows.

Table B-7 - Reaches for Flood Damage Analysis

Sheyenne River Reach	Reach Boundaries
1	Outlet to Baldhill Dam
2	Baldhill Dam to Kathryn, ND
3	Kathryn, ND to Soo Line RR
4	Soo Line RR to Kindred, ND
5	Kindred, ND to Horace, ND

Flooding impacts on cropland are evaluated using stage-area flooded relationships and downstream flow data for without- and with-project conditions. These impacts differ from impacts related to changes in water quality. Crop damage calculations for each reach were completed as follows: first, the number of acres flooded on each day of the growing season was calculated using the flow rate for the reach (output by the HEC-5/5Q model), along with the flow versus acres flooded relationship provided by the Corps for that reach. Next, the reach-specific crop damage per acre (from a seasonal crop damage curve) for each day of the growing season was multiplied by the number of acres flooded in that reach. This gave a value for the flood-induced crop damage for each day. Finally, from all the daily values of crop damage for the year, the maximum daily value was selected, and the maxima from all the reaches were summed to provide an annual crop damage amount. The without-project damage was subtracted from the with-project damage to give the damage (or benefit, if there is less damage with the project) attributable to the project.

Changes in flow volumes may also affect other agricultural property. This category includes farm buildings, machinery, stored grain, field damage, etc. For each of the traces analyzed, the annual daily maximum flow was found for each reach of the Sheyenne River. This annual daily maximum flow was translated to river stage using the reach-specific discharge-stage relationship. Then, the annual daily maximum stage was compared to the reach-specific stage-damage curve to provide the annual damage amount, by reach. Project damages for all reaches of the Sheyenne River were later summed to give an annual damage amount for the flood management alternative. For each Devils Lake flood management alternative, annual flood damages were computed for both the with-project and without-project conditions. The difference is the effect (benefit or disbenefit) assigned to the alternative evaluated.

Another category included in the downstream flood damage analysis is transportation infrastructure. This includes physical damage to roads, highways, railroads, and bridges as well as detour costs incurred by traffic during a flood event. For each of the traces analyzed, the annual daily maximum flow was found for each reach of the Sheyenne River. This annual daily maximum flow was translated to river stage using the reach-specific discharge-stage relationship provided by the Corps. Then, the annual daily maximum stage was compared to the reach-specific stage-damage curve to provide the annual damage amount, by reach. Project damages for all the reaches are later summed to give an annual damage amount for the flood management alternative. For each Devils Lake flood management alternative, annual flood damages are computed for both the with-project and without-project cases. The difference is the effect (benefit or disbenefit) assigned to the alternative evaluated.

Downstream impacts are considered at two urban centers on the Sheyenne River: Valley City and Lisbon. Other communities are not included as flow related impacts are not considered to be significant. Stage-damage relationships for Valley City and Lisbon were used as a basis for evaluating impacts of the outlet alternatives. For each of the traces analyzed, the annual daily maximum flow is found for the reach of the Sheyenne River in which the city of concern is located. This annual daily maximum flow was translated to river stage using the reach-specific discharge-stage relationship provided by the Corps. This annual daily maximum stage was then compared to the appropriate stage-damage curve to provide the annual damage amount for each city. For each Devils Lake flood management alternative, annual flood damages are computed for both the with-project and without-project cases.

6. SENSITIVITY ANALYSIS

Because of the many uncertainties inherent to this analysis, including projecting future lake levels and the human response to the rising lake, several baseline assumptions were modified in order to observe the effect that they may have on the feasibility of potential alternatives. These include:

- moderate hydrologic future with a peak lake elevation of 1455;
- a more moderate hydrologic future with a peak lake elevation of 1450;
- a dry hydrologic future with a peak lake elevation of 1448;
- an assumption that the natural outlet will erode when the lake overflows;
- an assumption that the State Water Commission will build a temporary outlet;
- Continued Infrastructure Protection;
- incremental justification of Dry Lake diversion.

6.1. Moderate and Dry Future Scenarios

The stochastic analysis provides an average economic estimate based on the probability of future lake levels. Because the recent lake levels have exceeded the predictions that have been based on historical lake levels, the wet future scenario analysis was also evaluated. However, it was necessary to also evaluate the economic feasibility of various alternatives based on average or dry scenarios to define the sensitivity under a wide range of potential futures.

This sensitivity analysis evaluated a set of three scenarios that are representative of three categories of future lake levels—a Dry Future and two Moderate Futures. These scenario analyses are representative of various categories within the stochastic traces, as noted.

Dry Future Scenario—The traces represented by this scenario generally show a decreasing pattern in the inflows and lake levels. The Dry Future represents those traces that have an average peak lake level of 1448 (approximately 36 percent of the stochastic traces). This dry future trace was obtained from within the stochastic traces, as a trace that was representative of this category.

Moderate Future 1 Scenario—Moderate Future 1 represents those traces that have an average peak lake level of 1450 (approximately 30 percent of the stochastic traces). This moderate future trace was obtained from within the stochastic traces, as a trace that was representative of this category.

Moderate Future 2 Scenario—Moderate Future 2 represents those traces that have an average peak lake level of 1455 (approximately 25 percent of the stochastic traces). This moderate future trace was obtained from within the stochastic traces, as a trace that was representative of this category.

Although the exact weather conditions assumed for these futures will probably never occur, examination of these futures helps determine the sensitivity of the model results to the assumptions made regarding future climatic and hydrologic conditions.

6.2. Erosion of the Natural Outlet

The analysis of alternatives assumed that there would be no erosion of the natural outlet or Tolna Coulee channel. This assumption was based on the conjecture that State or Federal agencies would protect the natural outlet at its current configuration in the case of a natural overflow. Because it is impossible to predict what may actually be implemented because of environmental, political, or social reasons, a sensitivity analysis of this assumption was necessary to define the degree of influence on the economic feasibility of the alternatives.

The erosion sensitivity analysis evaluates the impacts of erosion at the overflow point and adjacent upper reaches of Tolna Coulee. The coulee upper channel profile consists of two relatively steep sections located on both sides of a broad, flat marshy area that initially controls the outflow from Stump Lake. The upstream end of this marshy area is slightly higher than the initial Stump Lake overflow point. Erosion was assumed to start at the downstream end of this broad marshy area and proceed upstream to the overflow point. It was assumed that erosion would continue until the upper coulee becomes stable, a uniform slope having been achieved. Soil information at the natural outlet is limited but suggests the soils are moderate to highly erodible.

Based on the most recent surveys, overflow from Stump Lake occurs when the lake level reaches an elevation of 1459.1 ft. The analysis indicates that the outlet control point would slowly be eroded, with the maximum potential erosion occurring down to 1450.8.

Using sediment transport rates and the volume of overflow, the time for this erosion to occur was estimated to be approximately nine months. The sediment transport rates and associated discharge rating curves were used in the USGS model to evaluate the impacts on the lake level and downstream channel characteristics.

Under this analysis, a peak discharge of 1440 cfs was expected to occur during year 17. (This compares to a peak discharge of only 206 cfs when no erosion of the Tolna Coulee is assumed.) With erosion at the outlet, the peak lake level is reduced by 0.17 ft, and the duration of high lake levels is much shorter. Land adjacent to the lake will be relieved from flooding sooner if erosion occurs at the natural outlet. Therefore, landowners and farmers would be able to return to their land sooner.

6.3. Temporary Outlet

There is some uncertainty about the potential for construction of a temporary outlet by the State of North Dakota and whether or not this should be part of the without-project condition. The purpose of this outlet is to provide some immediate relief of flooding around the lake. The analysis to this point assumes that the outlet will not be built and is, therefore, not part of the without-project condition. A sensitivity analysis was performed to determine the effect on benefits if the temporary outlet is included in the without-project condition. The outlet would be constructed in 2003. Operation would begin in May 2004 with a capacity of 100 cfs increasing to 300 cfs by May 2006. The Pelican Lake 300-cfs outlet served as the basis for this evaluation to determine the sensitivity of this assumption to the analysis.

6.4. Continued Infrastructure Protection

Continued Infrastructure Protection involves protection of the features adjacent to the lake as they have been protected in the past. Due to the lack of economic feasibility for any outlet alternatives, this strategy may be all that can be implemented. This is the same strategy of protection that is assumed for the without-project condition (the most-likely strategy). It considers the feasibility of these actions, though, by comparing them against a condition where no damage preventive action is taken at all.

6.5. Incremental Justification of Dry Lake Diversion

An analysis was performed to determine the incremental feasibility of including the Dry Lake diversion as a feature of the Pelican Lake 300-cfs outlet alternative. The analysis was performed using the stochastic approach as well as the wet and two moderate future scenarios. Construction costs for the diversion are $9.92 million. Other costs considered are additional O&M costs and the difference in costs to raise levees along Hwy 281 and Hwy 19 above 1454 between the with- and without-Dry Lake diversion project.

7. ALTERNATIVES AND COSTS

The alternatives evaluated for reducing flood damage around Devils Lake are classified into three categories: those within the basin, outlet alternatives, and combination alternatives. The following table lists the alternatives analyzed.

Table B-8 - List of Alternatives Analyzed

<u>Alternatives Within the Basin</u>
- Upper Basin Management
- Expanded Infrastructure Measures
- Raise the Natural Outlet (Natural Overflow Protection)

<u>Outlet Alternatives</u>
- West Bay 300-cfs Constrained Outlet
- West Bay 480-cfs Unconstrained Outlet
- Pelican Lake 1 - 300-cfs Constrained Outlet
- Pelican Lake 1 - 480-cfs Unconstrained Outlet
- Pelican Lake 2 - 480-cfs Constrained Outlet
- Pelican Lake 3 - 480-cfs Constrained Outlet
- East End 480-cfs Unconstrained Outlet

<u>Combination Alternatives</u>
- Combination 1 - Upper Basin Management and Expanded Infrastructure Measures
- Combination 2 - West Bay 300-cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures

7.1. Upper Basin Management

The upper basin management alternative increases the amount of available upper basin storage volume in the watershed. Based on current studies by West Consulting, this is estimated to be approximately 50 percent of the total available upper basin storage. Implementation of this alternative would require placement of 39,681 acres of land into an upper basin storage program. Much of this land is currently prime farmland. Total cost, based on a cost/acre of $1,000, is estimated at $39,681,000. Included in the cost is:

- the cost to acquire the property (easement or lease),
- construction of outlet structures at storage sites as needed,
- administration and negotiations, including those to acquire land through condemnation,

- maintenance of outlet structures, and
- potential of removal of structures when lake recedes.

7.2. Expanded Infrastructure Measures

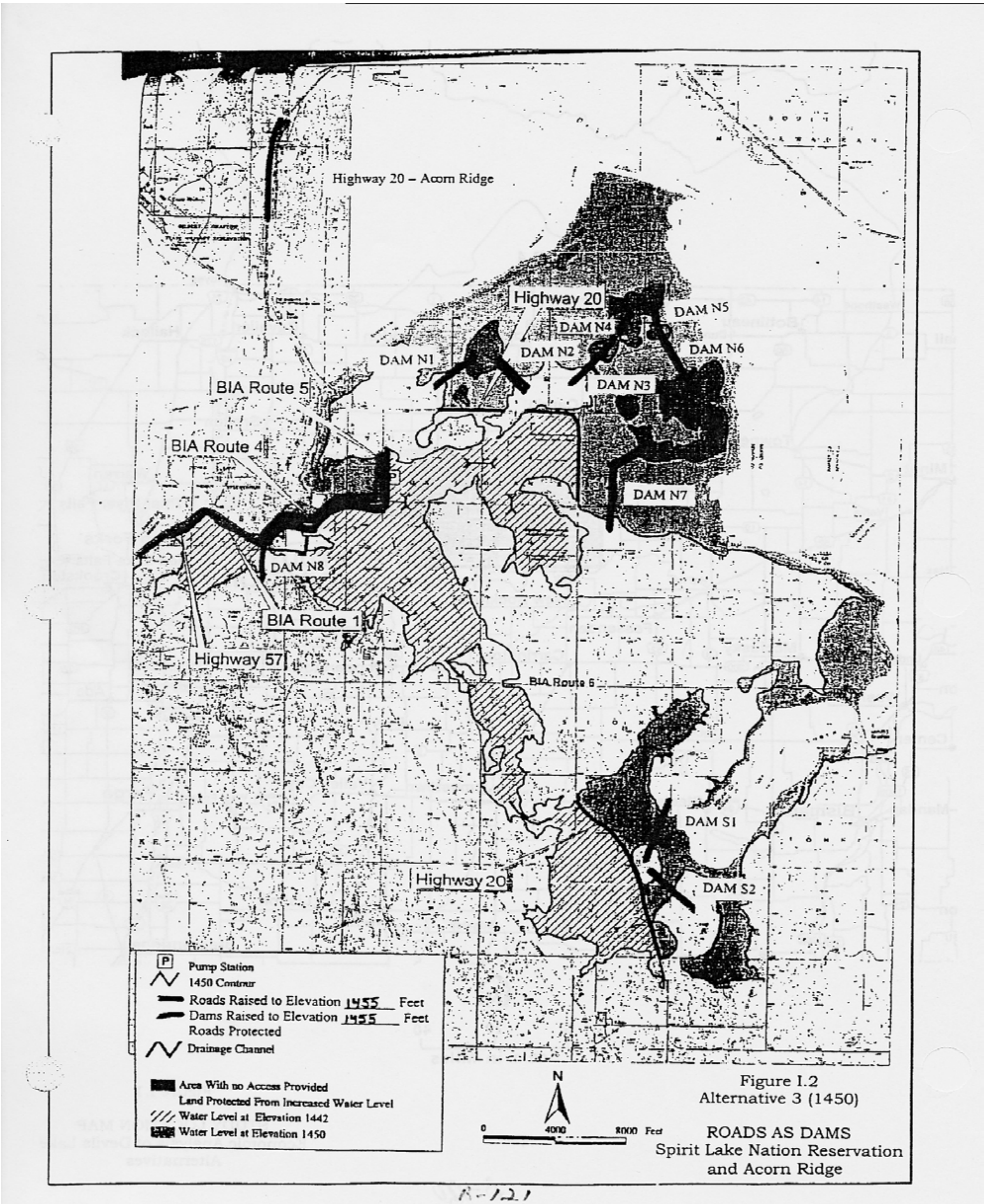
There are several locations around Devils Lake in which roads are currently holding back water, providing barriers to the rising and expanding waters of Devils Lake. Since these roads are acting as dams, but are not constructed to function as dams, there is a potential safety hazard to road users and to the people living behind and using the areas being sheltered by these barriers.

This alternative examines the economic feasibility of taking additional measures to provide a safe level of flood protection behind these barriers. The alternative assumes that several perimeter dams would be constructed between high ground (to minimize the number of roads that need to be raised) and that any remaining exterior roads would be converted to dams (including: Highway 20 near the Acorn Ridge development, BIA 4, and BIA 5). Figure B-2 shows the locations of these additional measures.

The construction costs for implementation of the expanded infrastructure measures alternative were obtained from the *Roadways Serving as Water Barriers Report,* Devils Lake Surface Transportation Task Force, May 2000. The project costs include:

- Costs to raise Highway 20 near Acorn Ridge, BIA 4, and BIA 5. These costs occur incrementally as necessary due to the rising lake levels. Inclusion of these raises as project costs was assumed to reduce the costs for raising road features and reduce the damages to land within the protected area.
- Costs for levee (perimeter dam) construction to connect high ground. These costs also occur incrementally as necessary due to the rising lake levels. Construction costs for these levee raises and for the previous item, raising Highway 20, are $32,000,000 for a lake level of 1450 (top of levee 1455) and $63,000,000 for a lake level of 1460 (top of levee 1465).
- Operation and maintenance costs for the new levees. Operation and maintenance costs were assumed to be 1 percent of the total project costs. These costs were

Figure B-2



Highway 20 – Acorn Ridge
Highway 20
DAM N1
DAM N2
DAM N3
DAM N4
DAM N5
DAM N6
DAM N7
DAM N8
BIA Route 5
BIA Route 4
BIA Route 1
Highway 57
BIA Route 6
DAM S1
DAM S2
Highway 20
Pump Station
1450 Contour
Roads Raised to Elevation 1455 Feet
Dams Raised to Elevation 1455 Feet
Roads Protected
Drainage Channel
Area With no Access Provided
Land Protected From Increased Water Level
Water Level at Elevation 1442
Water Level at Elevation 1450
N
0
4000
8000 Feet
Figure I.2
Alternative 3 (1450)
ROADS AS DAMS
Spirit Lake Nation Reservation
and Acorn Ridge
B-121

- assumed to include operation of temporary pumping stations to remove interior drainage and maintenance of the levees.

The protection that was provided by this alternative also changed the extent of damages prevented within this area. These damages prevented modified feature costs as follows:

- Feature 5 (St. Michael) - Relocation costs were eliminated.
- Feature 24 (BIA 6) - Road raise costs were eliminated.
- Feature 22 (Highway 20 Between Highway 57 and Tokio) - Road raise costs were revised to reflect only those costs for raising the segment between Highway 57 and BIA 5 (at the perimeter dam). The revised raises were computed at $4,574,000 at elevation 1454 and $6,48 1,000 at 1459.

- Feature 8.1 (Devils Lake Rural Areas) - Damages and relocation costs at action level 1446.2 were decreased to account for houses where access was restored. Homes that would be within the protected area include 7 homes on the reservation and 21 homes in the Acorn Ridge area (near Camp Grafton). The total reduction in damages to homes that are protected is $8,376,000. The total reduction in relocation costs was computed at $7,254,000. Land that is protected by this alternative (valued at $178,600) was also removed from the potential damages.

7.3. Raise the Natural Outlet

Raising the natural outlet is intended to prevent an overflow from Stump Lake to the Sheyenne River. To do this a permanent weir, with a top elevation of 1463, would be constructed. Downstream impacts would be reduced, but at the expense of increasing damages and costs to protect adjacent features around the lake.

The project costs for the raise natural outlet alternative include:

- cost to construct a permanent weir estimated at $1.3 million; construction assumed to occur when the lake level exceeds 1458, or 1 ft prior to overtopping the natural outlet; this occurs in year 2012 under the wet future scenario analysis;

- operation and maintenance of the weir structure, estimated at 1 percent of the total construction costs; starts in year 2013 under the wet future scenario analysis.

- purchase of additional land inundated by raising the lake level above the elevation at which it would have been without the weir (between 1460.6 and 1463); under the wet future scenario, it was assumed that 69,167 acres of land would be purchased, at a total land cost of $27,667,000; average cost of land estimated at $400 per acre;

- protection for features adjacent to the lake above the elevation at which the lake would have been without the weir (between 1460.6 and 1463); the following five features would be raised as necessary at the costs shown:

Feature 6	Grafton Military Reservation	$12,993,000
Feature 7	Grahams Island State Park	$6,300,000
Feature 17	Hwy 281 north of Hwy 2	$38,376,000
Feature 22	Hwy 20, between Hwy 57 and Tokio	$36,194,000
Feature 24	BIA Hwy 6	$6,262,000
Total		$100,125,000

- additional detour and restoration damages to roads and rail lines (between elevations 1460.6 and 1463).

7.4. Outlet Alternatives

Construction of the outlets was assumed to begin immediately and be operational in 2005. Costs for the outlets were assumed to be allocated in 2001.

7.4.1 West Bay Outlet

The West Bay outlet would draw water from the West Bay and direct it over the divide to the Sheyenne River via Peterson Coulee. Two projects were evaluated that use the West Bay outlet design—300-cfs constrained and 480-cfs unconstrained outlets. The 300-cfs constrained outlet was described in detail in *Devils Lake Emergency Outlet, Independent Assessment, Phase I,* Barr Engineering Company, October 30, 1997. The project costs for the West Bay outlets include:

- construction costs, at $58.5 million for the 300-cfs constrained outlet or $92.2 million for the 480-cfs unconstrained outlet.

- operation and maintenance costs for the outlet:

- average operating costs based on the yearly volume of water pumped; pump efficiency assumed to be 70 percent for the 300-cfs constrained and the 480-cfs unconstrained outlets; electrical costs were assumed to be $0.02245 per KWH; design head for both the 300-cfs constrained outlet and the 480-cfs unconstrained outlet assumed to be 240 ft.
- annual maintenance costs estimated at 1 percent of the first costs when outlet is operating and 0.5 percent of the first costs when outlet is not operating; first costs do not include the costs for engineering and design, supervision and administration, real estate, etc.

- one-time cost of replacement pumps in year 2026; replacement costs for the 300- cfs constrained outlet pumps were $2.6 million and for the 480-cfs unconstrained outlet pumps, $4.2 million.
- alternate water source or ion exchange unit installation at downstream municipal water treatment facilities if the 480-cfs unconstrained outlet is installed. Although the future water quality concentrations would not actually be known by facility operators in advance, an analysis of predicted future concentrations would likely occur as a basis for selection of water treatment methods. Therefore, the use of modeled future concentrations for identifying capital costs was assumed to be acceptable for the present reconnaissance-level economic analysis.

  The type of treatment system and the computed project cost at each facility under the various analyses are listed in Table I.3. These facility project costs were allocated in 2001.

- mitigation of downstream impacts to cultural resources, vegetation/wildlife/wetland resources, and aquatic resources; present worth costs were computed at $12.9 million for the 300-cfs constrained outlet, or $40.7 million for the 480-cfs unconstrained outlet.
  - annual monitoring costs of $650,000 along the downstream rivers to evaluate the impacts to groundwater, erosion/sedimentation, aquatic habitat, aquatic species composition, water quality, riparian vegetation, cultural resources, soil salinity, surface water users, and Sheyenne Delta vegetation.

7.4.2. Pelican Lake Outlets

Pelican Lake 1 (PL-1) - This version of the outlet project assumes construction of a 6.1 mile-long open channel to a pump station located on the north side of Minnewaukan. The existing embankments for Highways 281 and 19 would be used to keep the fresher water in Pelican Lake and the gravity channel separated from the West Bay of Devils Lake. The pump station and pipeline would be similar to that required for the West Bay outlet through Peterson Coulee, but would have higher head requirements due to the longer length of the pipeline. To provide additional fresh water, it was assumed that the Channel A control structure would be closed to allow flows from Dry Lake to flow into Mauvais Coulee.

Two projects were originally evaluated that use the Pelican Lake outlet design—300-cfs constrained and 480-cfs unconstrained outlets. The operation of the 300-cfs outlet is constrained by the Sheyenne River channel capacity and a 450 milligrams per liter (mg/l) sulfate standard. The project costs for the Pelican Lake outlets include:

- construction costs, at $84.2 million for the 300-cfs constrained outlet, or $129.2 million for the 480-cfs unconstrained outlet.
- operation and maintenance costs for the outlet:
    - average operating costs based on the yearly volume of water pumped. Pump efficiency was assumed to be 85 percent for the 300-cfs constrained and the 480-cfs unconstrained outlets. Electrical costs were assumed to be $0.02245 per KVVH. Design head for the 300-cfs constrained and the 480-cfs unconstrained outlets was assumed to be 270 ft.
    - annual maintenance costs estimated at 1 percent of the first costs when outlet is operating and 0.5 percent of the first costs when outlet is not operating; first costs do not include the costs for engineering and design, supervision and administration, real estate, etc
- one-time cost of replacement pumps in year 2026; replacement costs for the 300-cfs constrained outlet pumps were $3.0 million and for the 480-cfs unconstrained outlet pumps, $4.6 million •

- construction costs to raise control structures along Highway 281 and Highway 19. The raises for these control structures would be incurred incrementally as necessary due to the rising lake. Costs for these raises are listed in Table B-9 below. Raising these roads as part of the project was assumed to reduce the costs for raising these features. Table B-9 also lists the revised construction costs for raising these roads.

Table B-9 - Project Raise Costs - Pelican Lake Outlet Alternatives			
	Construction Costs	Revised Highway Raise Costs	
Elevation of Raise	(Project Costs)	Hwy 281	Hwy 19
1447.0		$ 3,829,000	
1448.0		$ 31,867,000	
1453.0		$ 37,695,000	
1454.0	$ 13,388,000		$ 26,444,000
1458.0		$ 45,593,000	
1459.0	$ 17,751,000		$ 41,410,000
1463.0		$ 42,134,000	

- operation and maintenance costs for the control structures along Highway 281 and Highway 19; assumed to be 1 percent of the first costs when outlet is operating and 0.5 percent of the first costs when outlet is not operating (because the lake level would be low).
- alternate water source or ion exchange unit installation at downstream municipal water treatment facilities if the 480-cfs unconstrained outlet is installed. Although the future water quality concentrations would not actually be known by facility operators in advance, an analysis of predicted future concentrations would likely occur as a basis for selection of water treatment methods. Therefore, the use of modeled future concentrations for identifying capital costs was assumed to be acceptable for the present reconnaissance-level economic analysis.
- mitigation of downstream impacts to cultural resources, vegetation/wildlife/wetland resources, and aquatic resources; present worth costs were computed at $12.9 million for the 300-cfs constrained outlet, or $40.7 million for the 480-cfs unconstrained outlet.

- annual monitoring costs of $650,000 along the downstream rivers to evaluate the impacts to groundwater, erosion/sedimentation, aquatic habitat, aquatic species composition, water quality, riparian vegetation, cultural resources, soil salinity, surface water users, and Sheyenne Delta vegetation.

Note: Subsequent to the earlier analysis of these two outlets, an additional analysis was conducted for a 300-cfs outlet with a lower sulfate constraint of 300 mg/l (from 450mg/l). In addition to the more restrictive operating constraint, project costs were further refined resulting in a significant escalation in project costs. On a present value basis, project costs rose from $117,451,000 to $208,420,000, an increase of over 77 percent. This new plan has been labeled the Pelican Lake 300/300 outlet, referring to the 300-cfs flow constaint and the 300mg/l sulfate constraint.

Pelican Lake 2 (PL-2) - The Pelican Lake PL-2 outlet attempts to capture more of the fresh water from the Mauvais Coulee than the PL-1 outlet. For this analysis, it was assumed that the water levels of Pelican Lake would be operated such that Pelican Lake would not be higher than Devils Lake. The outlet would also be constrained by water quality limitations in the downstream Sheyenne River. The outlet capacity is 480-cfs. The outlet includes construction of a levee system that is entirely separate from the Highway 19 and Highway 281 roadways. These levees would be constructed on the Pelican Lake side of these roads.

This version of the outlet project assumes construction of a drainage system to a pump station located on the north side of Minnewaukan. The pump station and pipeline would be similar to that required for the West Bay outlet through Peterson Coulee, but would have higher head requirements due to the longer length of the pipeline.

Project costs for Pelican Lake outlet PL2 include:

- construction costs, at $149.86 million for the 480-cfs constrained outlet ($98.72 million), Dry Lake outlet ($1.25 million), inlet channel from Pelican Lake ($9.82 million), embankment work for lake elevations up to 1454 ($35.77 million), culvert blocks in Highways 19 and 281 ($0.04 million), and Highway 19 control structure ($4.26 million).

- additional project costs for planning, engineering, design, supervision, administration, real estate, etc. were estimated to total $28.03 million.
- operation and maintenance costs for the outlet:
  - average operating costs based on the yearly volume of water pumped. Pump efficiency was assumed to be 85 percent for the 480-cfs constrained outlet. Electrical costs were assumed to be $0.02245 per KWH. Design head for the 480-cfs constrained outlets was assumed to be 270 ft.
  - annual maintenance costs estimated at 1 percent of the first costs when the outlet is operating and 0.5 percent of the first costs when the outlet is not operating; first costs do not include the costs for engineering and design, supervision and administration, real estate, etc.
- costs for providing replacement pumps in the year 2026 estimated at $4.6 million.
- costs to construct raises to the levees along Highway 281 and Highway 19 above 1454 (if needed). Costs for these incremental raises, which include engineering, design, supervision, administration, real estate, and environmental mitigation, are estimated at $11,304,000 for a raise to 1454 and $13,845,000 for the next raise to 1459.
- operation and maintenance costs for the control structures along Highway 281 and Highway 19. These costs are estimated at 1 percent of the first costs when the outlet is operating and 0.5 percent of the first costs when the outlet is not operating (because the lake level would be low).
- natural resource up-front mitigation costs within Pelican Lake; present worth costs were computed to be $10.45 million for the PL-2 outlet. This mitigation cost was added to the project costs for the stochastic, wet future, and both moderate model simulations. No natural resources mitigation costs within Pelican Lake were added to the up-front project costs for the dry future simulations because the lake recedes.
- mitigation of downstream impacts to cultural resources, vegetation/wildlife/wetland resources, and aquatic resources; present worth costs were computed at $12.9 million for the 480-cfs constrained outlet

- annual monitoring costs of $650,000 along the downstream rivers to evaluate the impacts to groundwater, erosion/sedimentation, aquatic habitat, aquatic species composition, water quality, riparian vegetation, cultural resources, soil salinity, surface water users, and Sheyenne Delta vegetation.

Pelican Lake 3 (PL-3) - The Pelican Lake PL-3 outlet is similar to the PL-2 outlet. It differs however, in that the water levels of Pelican Lake would be operated such that Pelican Lake would be allowed to rise up to elevation 1454 even if Devils Lake were much lower.

The project costs for the Pelican Lake outlet PL-3 include:

- construction costs, at $149.86 million for the 480-cfs constrained outlet ($98.72 million), Dry Lake outlet ($1.25 million), inlet channel from Pelican Lake ($9.82 million), embankment work for lake elevations up to 1454 ($35.77 million), culvert blocks in Highways 19 and 281 ($0.04 million), and Highway 19 control structure ($4.26 million).
- costs for planning, engineering, design, supervision, administration, real estate, etc. estimated to total $28.03 million.
- operation and maintenance costs for the outlet:
    - average operating costs based on the yearly volume of water pumped. Pump efficiency was assumed to be 85 percent for the 480-cfs constrained outlet. Electrical costs were assumed to be $0.02245 per KWH. Design head for the 480-cfs constrained outlets was assumed to be 270 ft.
    - annual maintenance costs estimated at 1 percent of the first costs when the outlet is operating and 0.5 percent of the first costs when the outlet is not operating; first costs do not include the costs for engineering and design, supervision and administration, real estate, etc
- costs for providing replacement pumps in year 2026 estimated at $4.6 million.
- costs to construct raises to the levees along Highway 281 and Highway 19 above 1454 (if needed) similar to that needed for PL 2 as described above.
- operation and maintenance costs for the control structures along Highway 281 and

Highway 19. These costs are estimated at 1 percent of the first costs when the outlet is operating and 0.5 percent of the first costs when the outlet is not operating (because the lake level would be low).

- purchase of additional land that is inundated by raising the level of Pelican Lake above the Devils Lake (between 1447 and 1454). Under the wet future scenario, it was assumed that 52,900 acres of land would be purchased, at a total land cost of $21,160,000. Land was estimated to cost $400 per acre.
- relocation of structures that would be inundated by raising Pelican Lake above Devils Lake. Based on USGS quadrangle maps approximately 41 houses would require relocation, at a total cost of $2,788,000. Each house was estimated to cost $88,000.
- protection of features within Pelican Lake up to elevation 1454. The following four features would be raised at the cost indicated. These raises were incurred in year 1 and are treated as project costs.

Feature 10	CPRR: City of Devils Lake to Harlowe	$24,597,000
Feature 11	BNRR along Hwy 2	$3,376,000
Feature 16	Hwy 281 south of Hwy 2	$26,100,000
Feature 17	Hwy 281 north of Hwy 2	$7,713,000
Total		$61,786,000

- natural resource up-front mitigation costs within Pelican Lake. Present worth costs were computed to be $21.66 million for the PL-3 outlet. This mitigation cost was added to the project costs for the stochastic, wet future, and both moderate model simulations. No natural resources mitigation costs within Pelican Lake were added to the up-front project costs for the dry future simulations because the lake recedes.
- mitigation of downstream impacts to cultural resources, vegetation/wildlife/wetland resources, and aquatic resources; present worth costs were computed at $12.9 million for the 480-cfs constrained outlet
- annual monitoring costs of $650,000 along the downstream rivers to evaluate the impacts to groundwater, erosion/sedimentation, aquatic habitat, aquatic species composition, water quality, riparian vegetation, cultural resources, soil salinity, surface water users, and Sheyenne Delta vegetation.

7.4.3. East End Outlet

This outlet extends from the east end of Devils Lake to and around Stump Lake and then across the natural outlet down Tolna Coulee to the Sheyenne River. It would be operated to allow 480 cfs to flow out of Devils Lake in an unconstrained manner. This alternative has the advantage of lower construction costs. But due to much poorer water quality, downstream impacts in terms of environmental effects and additional water treatment costs are severe.

The project costs for the East End 480-cfs unconstrained gravity outlet include:

- construction costs at $57.4 million.
- operation and maintenance costs, at 1 percent of the first costs. This was assumed to consist primarily of maintenance along the channel.
- alternate water source or ion exchange unit installation at downstream municipal water treatment facilities similar to that described for other outlet alternatives above.
- mitigation of downstream impacts to cultural resources, vegetation/wildlife/wetland resources, and aquatic resources; present worth costs were computed at $40.7 million
- annual monitoring costs of $650,000 along the downstream rivers to evaluate the impacts to groundwater, erosion/sedimentation, aquatic habitat, aquatic species composition, water quality, riparian vegetation, cultural resources, soil salinity, surface water users, and Sheyenne Delta vegetation

7.5 Combination Alternatives

7.5.1. Upper Basin Management and Expanded Infrastructure Measures

This alternative combines the upper basin management project with the expanded infrastructure measures project. The alternative assumes that storage in the upper basin would be combined with expanded flood protection measures to ensure safe protection of features adjacent to the lake. The project costs for the combination upper basin management and expanded infrastructure measures alternative include the combined costs listed in the sections above. These costs include the implementation of upper basin storage, raising three roads as dams (Highway 20 near Acorn Ridge, BIA 4, and BIA 5), and constructing perimeter dams to protect Highway 20 and other BIA roads south of Devils Lake. Both the without- and with-project conditions assume that the types of emergency measures currently being pursued in the basin would continue to be implemented as necessary as the lake continues to rise (but are not part of the project).

7.5.2. West Bay Outlet, Upper Basin Management, and Expanded Infrastructure Measures

This alternative combines the West Bay outlet with the upper basin management project and the expanded infrastructure measures project. In addition to construction of an outlet that releases flow from the West Bay, the alternative assumes that upper basin storage and the expanded flood protection measures would be implemented to ensure safe protection of features around the lake. The project costs for the combination West Bay 300-cfs constrained outlet, Upper Basin Management, and expanded infrastructure measures alternative include the combined costs listed in the pertinent sections above. These costs include outlet construction, outlet operation and maintenance, the implementation of upper basin storage, raising three roads as dams (Highway 20 near Acorn Ridge, BIA 4, and BIA 5), and constructing perimeter dams to protect Highway 20 and other BIA roads south of Devils Lake. Both the without- and with-project conditions assume that the types of emergency measures currently being pursued in the basin would continue to be implemented as necessary as the lake continues to rise (but are not part of the project).

8. RESULTS

Benefits around Devils Lake for an alternative are expressed as (1) the reduction in flood damages for those areas where no protection is provided and (2) the reduction in costs to protect the 24 features for which action would be taken to prevent damage as the lake rises. Downstream benefits may occur if the damages and costs under the without-project condition (as with a natural overflow) exceed those with an outlet in place. If an overflow does not occur under the without-project condition, damages and costs associated with the with-outlet condition will be greater than the without-project condition resulting in “disbenefits” attributed to the project.

Costs will include construction costs, operation and maintenance costs, treatment costs for water exiting Devils Lake, costs to mitigate the adverse environmental impacts downstream, and costs to monitor environmental conditions downstream.

Tables summarizing the results of the economic analysis appear at the end of Appendix B. They refer to the various approaches and scenarios as follows:

Stochastic Analysis	Tables ST-1 to ST-3
Wet Future Scenario	Tables WF-1 to WF-3
Moderate Future Scenario 1	Tables M1-1 to M1-3
Moderate Future Scenario 2	Tables M2-1 to M2-3
Dry Future Scenario	Tables DR-1 to DR-3

Note: Subsequent to the earlier work done by Barr, further refinements were made to the costs of the Pelican Lake outlet as well as its operation parameters. What emerged from these refinements was an outlet that was further constrained by a lower sulfate standard (450 mg/l to 300 mg/l) and cost significantly more to implement. On a present value basis, project costs increased from $117,451,000 to $208,420,000, an increase of over 77 percent. Table B-12 presents a comparison of the earlier version of the Pelican Lake 300-cfs outlet and the newer version refined to reflect updated costs and a more constrained operating plan.

8.1. Stochastic

Results of the stochastic analysis indicate that the Upper Basin Management plan and all of the outlet alternatives are not economically feasible for reducing damages around Devils Lake (Table ST-1). When downstream impacts are considered, net benefits are further reduced. This is especially evident for those outlets with an unconstrained operating plan. This indicates that the downstream costs and damages associated with an outlet are greater than those for the without-project condition, which may or may not include a natural overflow depending on the trace evaluated. Table ST-2 displays the benefits around Devils Lake divided into its separable elements: damage reduction benefits and feature protection cost savings benefits. Table ST-3 summarizes the downstream benefits (or disbenefits) by alternative.

The only alternative that appears feasible is the Expanded Infrastructure Measures plan with a benefit-cost ratio of 2.10. For a relatively low cost, this plan reduces damages in areas currently protected by roads acting as dams and eliminates the need for some relatively expensive road raises. However, many other features will still require damage prevention action as the lake rises and this plan does nothing to reduce the potential for a natural overflow. As a result, the local acceptance of this plan may be very limited.

8.2. Wet Future Scenario

Results from the analysis of the Wet Future scenario indicate that, when downstream impacts are included, all alternatives except the Raise Natural Outlet are economically feasible. The plan with the greatest net benefits, the NED plan, is the East End outlet. These plans are feasible because, under the wet scenario, a rising lake and a natural overflow are sure to happen. Each plan will reduce the lake peak, reduce future damages and feature protection costs, and reduce the likelihood of the natural overflow. The unconstrained outlets, while still feasible, generate significant adverse downstream impacts that lower their BCR's compared to effects just around Devils Lake. Tables WF-1 to WF-3 summarize the overall benefit-cost ratios, the benefits around Devils Lake and the downstream impacts.

8.3. Sensitivity Analysis

8.3.1. Moderate Future Scenario 1

For the Moderate Future 1 scenario (1450 peak lake level), only the outlet alternatives were evaluated. None of these alternatives proved feasible. Evidently when the lake rise is limited, there is not sufficient future damages or feature protection costs available as potential benefits for an outlet to offset its cost. The 480 cfs unconstrained outlets will have the largest effect in reducing damages to adjacent lake features and costs to protect these features. But they will also have the largest increase in damages to downstream features. Tables M1-1 to M1-3 summarize the economic results of this scenario.

8.3.2. Moderate Future Scenario 2

For the Moderate Future 2 scenario (1455 peak lake level), only the outlet alternatives were evaluated. Under this scenario, the Pelican Lake 300-cfs outlet is the only feasible plan when all impacts are considered. Combination plan 2 approaches feasibility with a BCR of 0.98. Evidently when the lake rises to a higher elevation, there are more future damages and feature protection costs available as potential benefits for an outlet. Like the previous scenario, the 480 cfs unconstrained outlets will have the greatest benefits to features adjacent to the lake and the largest increase in damages to downstream features. Tables M2-1 to M2-3 summarize the economic results of this scenario.

8.3.3. Dry Future Scenario

Under the Dry Future scenario, no alternatives are economically feasible. The lake does not rise any higher than its current level and no damages or feature protection costs are incurred in the future that an outlet can prevent. Tables DR-1 to DR-3 summarize the economic results of this scenario.

8.3.4. Erosion of Natural Outlet

The Pelican Lake 300/300 outlet was used to evaluate the effects of erosion of the natural outlet. It was evaluated under the Wet Future scenario. Results from this analysis indicate that, if the natural outlet is allowed to erode when the lake overflows, the benefit-cost ratio for the Pelican Lake 300/300 outlet increases from 1.54 to 1.86.

The erosion of the natural outlet does not significantly change the economic results for the features adjacent to the lake. This is to be expected, because modeling shows that the peak lake levels are only 0.17 ft lower than they would be if no erosion were assumed. Downstream damages, however, increase significantly when erosion of the natural outlet occurs during overflows. If it were assumed, therefore, that there was no erosion protection in place at the outlet, alternatives that prevent an overflow would show larger net benefits. These alternatives would prevent the larger downstream damages. This suggests that the net benefits of all the alternatives that prevent an overflow may have been somewhat underrated in this economic analysis. The without-project condition was always assumed to include erosion protection at the natural outlet, so the benefits of preventing erosion (by preventing an overflow) were hidden.

The primary increase in damages due to erosion is flow-related in urban areas during the year that the overflow takes place (increasing by more than $4 million average annual). The industrial water treatment and the urban flow-related damages increase by nearly 50 percent, municipal water treatment damages increase by about 8 percent, and other flow-related damages increase by 5 percent to 10 percent. Damages increase primarily during the first three years that the overflow takes place. By contrast, irrigation-related damages are decreased by nearly 60 percent. This decrease in damages is a result of fewer years of irrigated crop damage.

It should also be noted that the erosion of the natural outlet without project analysis does not include the additional damages that would occur due to the displacement and transport of the eroded material (approximately 937,000 cubic yards). This eroded material may cause additional physical and environmental damages in the downstream channel (in addition to those damages tabulated in this analysis). Including those additional damages in the analysis would increase the net benefits of the alternatives.

8.3.5. Temporary Outlet

The Pelican Lake 300-cfs 300mg/l constrained outlet was evaluated to determine the sensitivity of this assumption on the analysis. It was evaluated stochastically and under the wet and moderate future scenarios. Under each of these methodologies, the BCR for the outlet decreased when the temporary outlet was introduced as a component of the without-project condition. See Table B-13 for a summary of this analysis. The figures in this table can be compared with those in Table B-12 for the PL 300/300 plan to observe the effect of the temporary outlet.

For the stochastic analysis, benefits around Devils Lake for the Pelican Lake 300/300 outlet drop from $2,362,300 to $1,759,000 (a 25.5 percent reduction) when the temporary outlet is assumed in place for the without-project condition. The outlet has the effect of capturing some of the benefits and reducing those available for the permanent outlet. The impacts downstream are negligible. The constrained discharges from the temporary outlet have essentially no impact on water quality and quantity along the Sheyenne River. As without-project conditions with or without a temporary outlet are basically the same along the Sheyenne River, benefits for a permanent outlet will be the same. Due to the reduction in benefits around Devils Lake, the benefit-cost ratio drops from 0.19 to 0.13 when a temporary outlet is added to the without-project condition (based on set of most likely action strategies).

For the wet future scenario, the effect of the temporary outlet from a percentage benefit reduction perspective is less. Benefits around Devils Lake for a Pelican Lake 300-cfs outlet drop from $18,852,400 to $17,071,900 (a 9.4 percent reduction) when the temporary outlet is assumed in place for the without-project condition. Like the stochastic analysis, downstream impacts are negligible under the wet future scenario if a temporary outlet is operated in a constrained manner. The impact on the BCR, though, is significant. The benefit-cost ratio for the Pelican Lake 300/300 outlet drops from 1.54 to 1.17 under the wet future scenario (based on a set of most likely action strategies).

8.3.6. Dry Lake Diversion

To evaluate the economic feasibility of including the Dry Lake diversion as a feature of an outlet plan, the Pelican Lake 300/300 outlet was used. A comparison was made between the outlet with the diversion in place and the outlet without the diversion. The analysis proves that the diversion is incrementally feasible and including it as a feature of an outlet plan is justified. Benefits would be realized around Devils Lake as either savings of feature protection costs or reduction in flood damages. No downstream effects occur due to the constrained operation of the outlet. Table B-10 displays the results of this analysis.

Table B-10 - Summary of Incremental Analysis for Dry Lake Diversion

	Stochastic	Wet	Moderate 1	Moderate 2
Average Annual Benefits				
Costs Avoided	$ 629,300	$ 11,086,900	$ 1,211,900	$ 1,582,900
Damages Reduced	75,000	963,100	12,500	333,800
Total	704,300	12,050,000	1,224,400	1,916,700
Average Annual Costs	689,000	979,000	709,000	786,000
Benefit - Cost Ratio	1.02	12.31	1.73	2.44

8.3.7. Continued Infrastructure Protection (CIP)

This strategy is different than the other alternatives evaluated in that it is compared against a without-project condition that consists of no action taken to prevent flood damage while the other alternatives were evaluated against a most-likely without-project condition. The analysis is intended to show whether future emergency actions may be economically feasible. This is similar to analyses performed for advanced flood protection measures.

The CIP strategy has no computed effect on the peak lake levels. Similarly, this strategy will not reduce the natural overflows from Devils Lake. Therefore this strategy has no downstream impacts.

The benefits of the CIP strategy are limited to the reductions in infrastructure damages, which were computed to be $23.8 million under the stochastic analysis and $73.6 million under the wet future scenario analysis (using the set of most-likely action strategies as the with-project condition). These benefits represent a 95-percent decrease in total damages as a result of the flood protection measures.

The annual net benefit of this protection strategy equals the benefits less the costs, or $14.6 million under the stochastic analysis and $34.5 million under the wet future scenario analysis. The BCR is 2.57 for the stochastic analysis and 1.88 for the wet future scenario analysis. Because the net benefits are positive, the CIP strategy is cost-effective under both the stochastic and wet future scenario analyses when considered as an overall plan.

While the CIP strategy is economically feasible as a comprehensive plan for flood protection of features within the basin, it would be extremely difficult to provide centralized administration for an effort such as this. The complicated and difficult decision-making regarding individual features, currently accomplished autonomously and at a local level, would become the responsibility of a Federal agency. This responsibility would extend through many years, or perhaps indefinitely.

NOTE: The Continued Infrastructure Protection strategy was updated in the Fall of 2002 in an effort to refine the costs and benefits of the plan. As a result of this update, the BCR for the CIP strategy dropped from 2.57 to 1.07 for the stochastic analysis but stayed about the same for the wet future scenario, dropping only from 1.88 to 1.86. The BCR for the Moderate Future 1 is 0.93 and for the Moderate Future 2, 1.33. In addition to the update of costs and benefits, more attention was given to the incremental feasibility of each feature. Under the stochastic analysis 8 of the 24 features are incrementally feasible and under the wet future scenario 10 of the 24 features are incrementally feasible. Results of the updated analysis are summarized in Table B-11. For more details regarding the updated Infrastructure Protection study, see Chapter 5 of this report.

Table B-11 - Summary of Infrastructure Protection Plan (Stochastic and Wet Future Scenario)

Flood Protection Strategies up to Lake Level 1463

Feature Number	Feature Name	Flood Protection Strategy Having Largest Net Benefits	Present Worth[1]: Total First Costs	Present Worth[1]: Total Damages Prevented	Present Worth[1]: Annual Damages Prevented[2]	Stochastic Analysis: Average Annual Net Benefits[3]	Stochastic Analysis: Benefit-Cost Ratio	Wet Future Scenario: Average Annual Net Benefits[3]	Wet Future Scenario: Benefit- Cost Ratio
1	Churchs Ferry	Relocation of Structures	$ 1,946,000	$ 1,479,000	--	$ (6,100)	0.76	$ (22,400)	0.76
2	City of Devils Lake	Incremental Levee Raises	$ 78,174,000	$ 305,380,000	--	$ 365,200	1.30	$ 6,972,700	2.84
3	Fort Totten	Incremental Relocations	$ 5,367,000	$ 4,086,000	--	$ (20,500)	0.76	$ (65,600)	0.76
4	City of Minnewaukan	Incremental Levee Raises	$ 17,605,000	$ 25,042,000	--	$ (25,300)	0.88	$ 149,700	1.17
5	St. Michael	Incremental Relocations	$ 1,720,000	$ 1,224,000	--	$ (11,700)	0.71	$ (21,200)	0.71
6	Gilbert C. Grafton Military Reservation	Relocation of Munitions Facility	$ 1,514,000	$ 970,000	--	$ (33,000)	0.64	$ (33,100)	0.64
7	Grahams Island State Park	Incremental Road Raises and Structure Relocations	$ 23,764,000	$ 2,718,000	$ 516,000	$ (66,400)	0.86	$ (414,400)	0.59
8.1	Devils Lake Rural Areas	Incremental Relocations	$ 79,764,000	$ 58,670,000	--	$ (273,700)	0.72	$ (831,300)	0.73
8.2	Stump Lake Rural Areas	Incremental Relocations	$ 5,457,000	$ 3,547,000	--	$ (28,700)	0.65	$ (87,700)	0.65
9	Red River Valley and Western Railroad	N/A	--	--	--	--	--	--	--
10	Canadian Pacific Railroad	Incremental Rail Raises	$ 67,260,000	--	$ 533,000	$ (895,900)	0.48	$ (2,646,700)	0.17
11	Burlington Northern Railroad (along US Highway 2)	Raise Rail to Maximum Level	$ 48,583,000	--	$ 4,333,000	$ (62,600)	0.87	$ 1,060,300	1.48
12	Burlington Northern Railroad (Churchs Ferry to Cando)	Incremental Rail Raises	$ 69,394,000	--	$ 509,000	$ (179,100)	0.19	$ (1,595,500)	0.20
13	US Highway 2	Incremental Road Raises	$ 152,738,000	--	$ 11,863,000	$ 88,200	1.15	$ 2,298,800	1.47
14	ND Highway 57 (between ND Highway 20 and BIA Highway 1)	Incremental Road Raises	$ 14,274,000	--	$ 13,104,000	$ 646,100	11.57	$ 7,251,000	16.25
15	ND Highway 57 (between BIA Highway 1 and US Highway 281)	Incremental Road Raises	$ 42,667,000	--	$ 9,488,000	$ 353,400	3.05	$ 4,250,500	4.05
16	US Highway 281 (South of US Highway 2)	Relocation of Road	$ 46,031,000	--	$ 3,861,000	$ 315,600	1.11	$ 2,733,000	1.98
17	US Highway 281 (North of US Highway 2)	Incremental Road Raises	$ 38,459,000	--	$ 1,403,000	$ (35,200)	0.85	$ (198,300)	0.86
18	ND Highway 19	Incremental Road Raises	$ 101,252,000	--	$ 1,322,000	$ (289,000)	0.29	$ (2,379,100)	0.28
19	ND Highway 1	- NA -	--	--	--	--	--	--	--
20	ND Highway 20 (North of City of Devils Lake)	Incremental Road Raises	$ 33,382,000	--	$ 3,375,000	$ (26,200)	0.66	$ (29,100)	0.97
21	ND Highway 20 (City of Devils Lake Dike to ND Highway 57)	Incremental Road Raises	$ 24,859,000	--	$ 13,104,000	$ 606,900	6.71	$ 6,915,500	9.35
22	ND Highway 20 (between ND Highway 57 and Tokio)	Incremental Road Raises	$ 37,987,000	--	$ 611,000	$ (592,300)	0.50	$ (1,210,800)	0.34
23	BIA Highway 1	Incremental Road Raises	$ 11,382,000	--	$ 1,012,000	$ 188,400	2.08	$ 469,100	1.97
24	BIA Highway 6[5]	Incremental Road Raises	$ 8,442,000	--	$ 13,873,000	$ 740,900	35.46	$ 8,016,700	52.59
CUMULATIVE TOTAL			**$ 912,021,000**	**$ 403,116,000**	**$ 78,907,000**	**$ 759,000**	**1.07**	**$ 30,582,100**	**1.86**

Summary Including Roads Acting as Dams

Feature Number	Feature Name	Flood Protection Strategy Having Largest Net Benefits	Total First Costs	Total Damages Prevented	Annual Damages Prevented	Stochastic: Average Annual Net Benefits	Stochastic: Benefit-Cost Ratio	Wet Future: Average Annual Net Benefits	Wet Future: Benefit- Cost Ratio
5	St. Michael	Protected by Roads Acting as Dams	--	$ 1,224,000	--	$ -	--	$ -	--
22	ND Highway 20 (between ND Highway 57 and Tokio)	Protected by Roads Acting as Dams	--	--	$ 611,000	$ -	--	$ -	--
24	BIA Highway 6[5]	Protected by Roads Acting as Dams	--	--	$ 13,873,000	$ -	--	$ -	--
25.1	Roads Acting as Dams (Acorn Ridge Area)	Incremental Levee Raises	$ 15,209,000	$ 3,098,000	$ -	$ (468,500)	0.12	$ (193,400)	0.21
25.2	Roads Acting as Dams (Mission Township Area)[6]	Incremental Levee Raises	$ 87,509,000	$ 7,220,000	$ -	$ (1,410,200)	0.61	$ (166,100)	0.93
CUMULATIVE TOTAL WITH ROADS ACTING AS DAMS			**$ 966,590,000**	**$ 413,434,000**	**$ 78,907,000**	**$ (1,256,600)**	**0.91**	**$ 23,437,900**	**1.65**

Notes

1. Total first costs are actual flood protection costs, in present value. Values for damages and annual damages are also listed in present value.
2. Annual damages prevented during years that the feature would have been damaged by the lake. The benefit of avoiding restoration damages (damages registered when a previously inundated road or railroad is repaired and made ready for use again) is not represented in this table.
3. The net benefits listed were averaged over 10,000 traces. The averages were then annualized over a 50-year period.
4. Currently protected by temporary dikes and roads that are acting as dams.
5. Currently protected by temporary dikes and roads that are acting as dams, and is being raised to a minimum elevation of 1456.9.
6. Damages prevented listed for Roads Acting as Dams include: protection of St. Michael structures and detours around the lake when BIA Highway 6 and ND Highway 20 are closed. These damages represent the benefits to the entire Infrastructure Protection system; compares to the Expanded Infrastructure Measures evaluated in the previous economic analysis.

Table 12 - Comparison between PL 300-cfs/450 mg/l outlet and PL 300-cfs/300 mg/l outlet								
	Stochastic		Wet Future		Moderate Future 1		Moderate Future 2	
	PL 300/450	PL 300/300	PL 300/450	PL 300/300	PL 300/450	PL 300/300	PL 300/450	PL 300/300
Benefits Around Lake								
Costs Avoided	$ 2,538,900	$ 2,179,200	$ 17,519,800	$ 17,488,400	$ 2,562,900	$ 1,562,800	$ 10,388,200	$ 7,279,800
Damage Reduction	230,900	183,100	1,364,000	1,364,000	558,700	214,300	806,700	598,800
	2,769,800	2,362,300	18,883,800	18,852,400	3,121,600	1,777,100	11,194,900	7,878,600
Downstream Effects	134,000	232,000	3,028,000	3,702,000	(132,000)	70,000	(115,000)	(61,000)
Total Benefits	2,903,800	2,594,300	21,911,800	22,554,400	2,989,600	1,847,100	11,079,900	7,817,600
Present Value Costs	117,451,000	208,420,000	130,721,000	218,782,000	117,248,000	209,340,000	119,857,000	211,795,000
Average Annual Costs	7,844,000	13,920,000	8,731,000	14,612,000	7,831,000	13,982,000	8,005,000	14,146,000
Benefit - Cost Ratio	0.37	0.19	2.51	1.54	0.38	0.13	1.38	0.55

Table 13 - Economic Summary of Pelican Lake 300/300 Outlet with Temporary Outlet Included in Without Project Condiiton				
	Stochastic	Wet Future	Moderate Future 1	Moderate Future 2
Benefits Around Lake				
Costs Avoided	$ 1,625,500	$ 15,814,900	$ 1,369,600	$ 6,957,400
Damage Reduction	133,500	1,257,000	26,400	596,700
	1,759,000	17,071,900	1,396,000	7,554,100
Downstream Effects	-	-	-	-
Total Benefits	1,759,000	17,071,900	1,396,000	7,554,100
Present Value Costs	208,420,000	218,782,000	209,340,000	211,795,000
Average Annual Costs	13,920,000	14,612,000	13,982,000	14,146,000
Benefit - Cost Ratio	0.13	1.17	0.10	0.53

Economic Analysis of Devils Lake Alternatives

Table ST-1

Cost and Benefit Comparison - Stochastic Analysis

(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Devils Lake Basin Only				Including Downstream Impacts			
		Ann. Costs	Ann. Bens	Net Bens	BCR	Ann. Costs	Annual Benefits	Net Benefit	BCR
ST-1	Upper Basin Management	$2,650	$773	-$1,877	0.29	NA	NA	NA	NA
ST-2b	Expanded Infrastructure Measures	$1,149	$2,410	$1,261	2.10	1,149	$2,410	$1,261	2.10
ST-3	West Bay 300 cfs Constrained Outlet	$4,335	$1,477	-$2,858	0.34	5,847	$1,641	-$4,205	0.28
ST-4	West Bay 480 cfs Unconstrained Outlet	$6,941	$3,414	-$3,527	0.49	11,232	$119	-$11,113	0.01
ST-5	Pelican Lake 1 - 300 cfs Constrained Outlet	$6,285	$2,771	-$3,515	0.44	7,797	$2,905	-$4,892	0.37
ST-6	Pelican Lake 1 - 480 cfs Unconstrained Outlet	$9,585	$3,718	-$5,867	0.39	13,790	$1,428	-$12,362	0.10
ST-7b	Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	$3,717	$3,131	-$586	0.84	NA	NA	NA	NA
ST-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$7,934	$4,197	-$3,738	0.53	9,446	$4,363	-$5,083	0.46
ST-10	East End 480 cfs Unconstrained Outlet	$3,869	$3,414	-$455	0.88	7,238	$118	-$7,121	0.02
ST-11	Pelican Lake 2 - 480 cfs Constrained Outlet	$13,691	$2,182	-$11,509	0.16	15,202	$2,131	-$13,071	0.14
ST-12	Pelican Lake 3 - 480 cfs Constrained Outlet	$20,134	$4,491	-$15,643	0.22	21,647	$4,442	-$17,205	0.21

N.A. - The downstream impacts for the stochastic scenario were computed based on the weighted averages of the sensitivity scenarios. Not all of the alternatives were analyzed in the sensitivity analyses, therefore the downstream impacts are not computable.

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Economic Analysis of Devils Lake Alternatives

Table ST-2

Comparison of Benefits for Features Adjacent to Devils Lake - Stochastic Analysis

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Set of Feature Strategy Costs	Benefits To Adjacent Lake Features
ST-1	Upper Basin Management	Without-Project	$1,285	$10,521	
		With-Project	$1,209	$9,824	
		Total Benefits	$75	$697	$773
ST-2b	Expanded Infrastructure Measures	Without-Project	$1,285	$10,521	
		With-Project	$1,279	$8,117	
		Total Benefits	$5	$2,405	$2,410
ST-3	West Bay 300 cfs Constrained Outlet	Without-Project	$1,285	$10,521	
		With-Project	$1,159	$9,170	
		Total Benefits	$125	$1,352	$1,477
ST-4	West Bay 480 cfs Unconstrained Outlet	Without-Project	$1,285	$10,521	
		With-Project	$953	$7,440	
		Total Benefits	$331	$3,081	$3,412
ST-5	Pelican Lake 300 cfs Constrained Outlet	Without-Project	$1,285	$10,521	
		With-Project	$1,054	$7,983	
		Total Benefits	$231	$2,539	$2,770
ST-6	Pelican Lake 480 cfs Unconstrained Outlet	Without-Project	$1,285	$10,521	
		With-Project	$953	$7,137	
		Total Benefits	$331	$3,385	$3,716
ST-7b	Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	Without-Project	$1,285	$10,521	
		With-Project	$1,204	$7,471	
		Total Benefits	$81	$3,050	$3,131
ST-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	Without-Project	$1,285	$10,521	
		With-Project	$1,106	$6,504	
		Total Benefits	$178	$4,018	$4,196
ST-10	East End 480 cfs Unconstrained Outlet	Without-Project	$1,285	$10,521	
		With-Project	$953	$7,440	
		Total Benefits	$331	$3,081	$3,412
ST-11	Pelican Lake 2	Without-Project	$1,285	$10,521	
		With-Project	$1,085	$8,539	
		Total Benefits	$200	$1,982	$2,182
ST-12	Pelican Lake 3	Without-Project	$1,285	$10,521	
		With-Project	$740	$6,575	
		Total Benefits	$545	$3,946	$4,491

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Economic Analysis of Devils Lake Alternatives

Table ST-3

Stochastic Analysis - Comparison of Benefits for Downstream Features (Weighted Average)[1]

(Average Annual Dollars in Thousands)

Alternative Number	Future	Water Treatment Damages: Municipal	Water Treatment Damages: Industrial	Flow Related Damages: Ag-Crop	Flow Related Damages: Ag-Other	Flow Related Damages: Urban	Flow Related Damages: Transportation	Irrigation	Overall Benefits[2]
ST-1	Without Project	NA	NA	NA	NA	NA	NA	NA	
UBM	With Project	NA	NA	NA	NA	NA	NA	NA	
	Total Benefits	NA	NA	NA	NA	NA	NA	NA	NA
ST-2b	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49	
EIM	With Project	$259	$4	$435	$158	$8,567	$1,824	$49	
	Total Benefits	$0	$0	$0	$0	$0	$0	$0	$0
ST-3	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49	
WB 300	With Project	$22	$13	$446	$158	$8,639	$1,826	$27	
	Total Benefits	$237	-$9	-$11	$0	-$72	-$2	$22	$164
ST-4	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49	
WB 480	With Project	$3,124	$55	$471	$160	$8,676	$1,837	$267	
	Total Benefits	-$2,865	-$51	-$36	-$2	-$109	-$13	-$219	-$3,295
ST-5	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49	
PL 300	With Project	$26	$17	$458	$159	$8,649	$1,828	$24	
	Total Benefits	$233	-$13	-$23	-$1	-$82	-$4	$24	$134
ST-6	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49	
PL 480	With Project	$2,221	$38	$472	$160	$8,676	$1,838	$180	
	Total Benefits	-$1,962	-$34	-$37	-$2	-$109	-$14	-$131	-$2,290
ST-7b	Without Project	NA	NA	NA	NA	NA	NA	NA	
UBM, EIM	With Project	NA	NA	NA	NA	NA	NA	NA	
	Total Benefits	NA	NA	NA	NA	NA	NA	NA	NA
ST-8b	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49	
UBM, EIM,	With Project	$21	$13	$445	$158	$8,638	$1,825	$28	
WB 300	Total Benefits	$238	-$9	-$10	$0	-$71	-$2	$21	$166
ST-10	Without Project	NA	NA	NA	NA	NA	NA	NA	
EE 480	With Project	NA	NA	NA	NA	NA	NA	NA	
	Total Benefits	NA	NA	NA	NA	NA	NA	NA	NA
ST-11	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49	
PL 2	With Project	$10	$7	$459	$159	$8,875	$1,830	$4	
	Total Benefits	$249	-$3	-$24	-$1	-$308	-$6	$45	-$48
ST-12	Without Project	$259	$4	$435	$158	$8,567	$1,824	$49	
PL 3	With Project	$10	$7	$457	$159	$8,872	$1,833	$5	
	Total Benefits	$249	-$3	-$22	-$1	-$305	-$9	$44	-$47

[1]For the purposes of including the impact of downstream features on the overall BCR of the stochastic traces, these values are a weighted average of the annualized damages and benefits for the downstream features during wet (WF), moderate-wet (M1), moderate-dry (M2) and dry (DR) based on the percentage of the 10,000 traces that fall into these four categories. If the weighted average is "NA", there was no data to compute the weighted average.

[2]This value includes only damages prevented by the project. Capital costs associated with outlet projects are considered project costs, and are therefore counted as an up-front cost rather than a damage.

Economic Analysis of Devils Lake Alternatives
Table WF-1

Wet Future Scenario Cost and Benefit Comparison
(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Devils Lake Basin Only				Including Downstream Impacts			
		Ann. Costs	Ann. Bens	Net Bens	BCR	Ann. Costs	Ann. Bens	Net Bens	BCR
WF-1	Upper Basin Management	$2,650	$2,584	-$66	0.98	2,650	$3,191	$541	1.20
WF-2b	Expanded Infrastructure Measures	$4,063	$4,301	$238	1.06	4,063	$4,301	$238	1.06
WF-3	West Bay 300 cfs Constrained Outlet	$4,864	$16,760	$11,896	3.45	6,376	$19,718	$13,341	3.09
WF-4	West Bay 480 cfs Unconstrained Outlet	$7,795	$29,732	$21,938	3.81	12,188	$28,828	$16,640	2.37
WF-5	Pelican Lake 1 - 300 cfs Constrained Outlet	$7,242	$18,884	$11,642	2.61	8,731	$21,912	$13,181	2.51
WF-6	Pelican Lake 1 - 480 cfs Unconstrained Outlet	$10,430	$29,943	$19,512	2.87	14,668	$30,198	$15,530	2.06
WF-7b	Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	$6,491	$6,706	$214	1.03	6,491	$7,313	$821	1.13
WF-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$9,654	$22,537	$12,883	2.33	11,165	$25,489	$14,324	2.28
WF-9	NOTE: WF-9 is the base condition – without project future condition.								
WF-10	East End 480 cfs Unconstrained Outlet	$3,869	$29,732	$25,863	7.68	9,885	$28,201	$18,315	2.85
WF-11	Raise Natural Outlet	$20,824	$13,858	-$6,966	0.67	20,824	$17,299	-$3,525	0.83
WF-15	Pelican Lake 2 - 480 cfs Constrained	$14,658	$21,733	$7,075	1.48	16,170	$22,302	$6,132	1.38
WF-16	Pelican Lake 3 - 480 cfs Constrained	$21,241	$27,249	$6,008	1.28	22,753	$27,804	$5,051	1.22

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions).

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits.

Economic Analysis of Devils Lake Alternatives

Table WF-2

Wet Future Scenario Comparison of Benefits for Features Adjacent to Devils Lake

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Set of Feature Strategy Costs	Benefits To Adjacent Lake Features
		Without-Project	$4,141	$39,335	
		With-Project	$3,915	$36,977	
WF-1	Upper Basin Management	Total Benefits	$226	$2,358	$2,584
		Without-Project	$4,141	$39,335	
		With-Project	$4,133	$35,042	
WF-2b	Expanded Infrastructure Measures	Total Benefits	$9	$4,293	$4,301
		Without-Project	$4,141	$39,335	
		With-Project	$2,835	$23,881	
WF-3	West Bay 300 cfs Constrained Outlet	Total Benefits	$1,307	$15,454	$16,760
		Without-Project	$4,141	$39,335	
		With-Project	$1,810	$11,935	
WF-4	West Bay480 cfs Unconstrained Outlet	Total Benefits	$2,331	$27,400	$29,731
		Without-Project	$4,141	$39,335	
		With-Project	$2,777	$21,815	
WF-5	Pelican Lake 300 cfs Constrained Outlet	Total Benefits	$1,364	$17,520	$18,884
		Without-Project	$4,141	$39,335	
		With-Project	$1,810	$11,724	
WF-6	Pelican Lake 480 cfs Unconstrained Outlet	Total Benefits	$2,331	$27,611	$29,942
		Without-Project	$4,141	$39,335	
		With-Project	$3,907	$32,864	
WF-7b	Combination 1 – Upper Basin Management and Expanded Infrastructure Measures	Total Benefits	$235	$6,471	$6,706
		Without-Project	$4,141	$39,335	
		With-Project	$2,696	$18,244	
WF-8b	Combination 2 – West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	Total Benefits	$1,445	$21,091	$22,537
WF-9	NOTE: WF-9 is the w/out project future condition.				
		Without-Project	$4,141	$39,335	
		With-Project	$1,810	$11,935	
WF-10	East End 480 cfs Unconstrained Outlet	Total Benefits	$2,331	$27,400	$29,731
		Without-Project	$3,433	$39,398	
		With-Project	$3,066	$25,907	
WF-11	Raise Natural Outlet	Total Benefits	$367	$13,491	$13,858
		Without-Project	$4,141	$39,335	
		With-Project	$2,372	$19,372	
WF-15	Pelican Lake 2	Total Benefits	$1,769	$19,963	$21,732
		Without-Project	$4,141	$39,335	
		With-Project	$1,300	$14,928	
WF-16	Pelican Lake 3	Total Benefits	$2,841	$24,407	$27,248

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions).

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of of damages and benefits.

Economic Analysis of Devils Lake Alternatives
Table WF-3
Wet Future Scenario Comparison of Benefits for Downstream Features
(Average Annual Dollars in Thousands)

Alternative Number	Future	Water Treatment Damages		Flow Related Damages				Irrigation	Overall Benefits[1]
		Municipal	Industrial	Ag-Crop	Ag-Other	Urban	Transportation		
WF-1	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	With Project	$2,283	$32	$509	$207	$9,264	$2,350	$421	
	Total Benefits	$443	$10	$6	$1	$83	$6	$58	$607
WF-2a	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	With Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	Total Benefits	$0	$0	$0	$0	$0	$0	$0	$0
WF-2b	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	With Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	Total Benefits	$0	$0	$0	$0	$0	$0	$0	$0
WF-3	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	With Project	$54	$39	$550	$208	$9,470	$2,358	$37	
	Total Benefits	$2,672	$4	-$35	$0	-$123	-$3	$442	$2,957
WF-4	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	With Project	$3,599	$69	$592	$210	$9,546	$2,382	$179	
	Total Benefits	-$873	-$27	-$78	-$2	-$199	-$26	$300	-$904
WF-5	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	With Project	$29	$22	$550	$208	$9,463	$2,357	$16	
	Total Benefits	$2,697	$21	-$35	$1	-$116	-$2	$463	$3,028
WF-6	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	With Project	$2,545	$46	$591	$210	$9,546	$2,378	$101	
	Total Benefits	$181	-$4	-$77	-$1	-$199	-$22	$378	$256
WF-7a	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	With Project	$2,283	$32	$509	$207	$9,264	$2,350	$421	
	Total Benefits	$443	$10	$6	$1	$83	$6	$58	$607
WF-7b	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	With Project	$2,283	$32	$509	$207	$9,264	$2,350	$421	
	Total Benefits	$443	$10	$6	$1	$83	$6	$58	$607
WF-8a	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	With Project	$53	$38	$549	$208	$9,464	$2,358	$51	
	Total Benefits	$2,673	$4	-$34	$1	-$117	-$2	$428	$2,953
WF-16	Without Project	$2,726	$42	$515	$208	$9,347	$2,356	$479	
	With Project	$19	$15	$585	$216	$11,871	$2,400	$11	
	Total Benefits	$2,707	$27	-$70	-$8	-$2,524	-$44	$468	$556

[1]This value includes only damages prevented by the project. Capital costs associated with outlet projects are considered project costs, and are therefore counted as an up-front cost rather than a damage.

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of of damages and benefits.

Economic Analysis of Devils Lake Alternatives

Table M1-1

Moderate Future 1 Scenario (1450 Peak Lake Level) Cost and Benefit Comparison

(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Devils Lake Basin Only				Including Downstream Impacts			
		Ann. Costs	Ann. Bens	Net Bens	BCR	Ann. Costs	Ann. Bens	Net Bens	BCR
M1-1	West Bay 300 cfs Constrained Outlet	$4,327	$644	-$3,683	0.15	$ 5,839	$568	-$5,271	0.10
M1-2	West Bay 480 cfs Unconstrained Outlet	$6,904	$3,123	-$3,781	0.45	$ 11,357	-$728	-$12,085	-0.06
M1-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$6,965	$3,557	-$3,408	0.51	$ 8,476	$3,482	-$4,994	0.41
M1-5	Pelican Lake 1 - 300 cfs Constrained Outlet	$6,319	$3,122	-$3,197	0.49	$ 7,831	$2,990	-$4,841	0.38
M1-6	Pelican Lake 1 - 480 cfs Unconstrained Outlet	$9,551	$3,123	-$6,428	0.33	$ 13,791	-$179	-$13,970	-0.01
M1-7	Pelican Lake 2 - 480 cfs Constrained Outlet	$13,590	$1,619	-$11,971	0.12	$ 15,169	$1,593	-$13,576	0.11
M1-8	Pelican Lake 3 - 480 cfs Constrained Outlet	$20,260	$3,214	-$17,046	0.16	$ 21,638	$3,178	-$13,970	0.15

N.A. - The downstream impacts for the stochastic scenario were computed based on the weighted averages of the sensitivity scenarios. Not all of the alternatives were analyzed in the sensitivity analyses, therefore the downstream impacts are not computable.

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features aer not protected or are abandoned.

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits.

Economic Analysis of Devils Lake Alternatives

Table M1-2

Moderate Future 1 Scenario (1450 Peak Lake Level) Comparison of Benefits for Features Adjacent to Devils Lake

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Set of Feature Strategy Costs	Benefits To Adjacent Lake Features
		Without-Project	$917	$5,681	
		With-Project	$715	$5,240	
M1-1	West Bay 300 cfs Constrained Outlet	Total Benefits	$202	$442	$644
		Without-Project	$917	$5,681	
		With-Project	$358	$3,119	
M1-2	West Bay 480 cfs Unconstrained Outlet	Total Benefits	$559	$2,563	$3,122
		Without-Project	$917	$5,681	
		With-Project	$698	$2,344	
M1-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	Total Benefits	$219	$3,338	$3,557
		Without-Project	$917	$5,681	
		With-Project	$358	$3,119	
M1-5	Pelican Lake 300 cfs Constrained Outlet	Total Benefits	$559	$2,563	$3,122
		Without-Project	$917	$5,681	
		With-Project	$358	$3,119	
M1-6	Pelican Lake 480 cfs Unconstrained Outlet	Total Benefits	$559	$2,563	$3,122
		Without-Project	$917	$5,681	
		With-Project	$703	$4,276	
M1-7	Pelican Lake 2	Total Benefits	$214	$1,405	$1,619
		Without-Project	$917	$5,681	
		With-Project	$292	$3,093	
M1-8	Pelican Lake 3	Total Benefits	$625	$2,588	$3,213
		Without-Project	$917	$5,681	
		With-Project	$703	$4,119	
M1-9	Pelican Lake 300 cfs Constrained Outlet (300mg/l)	Total Benefits	$214	$1,562	$1,776

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits.

Economic Analysis of Devils Lake Alternatives

Table M1-3

Moderate Future 1 Scenario (1450 Peak Lake Level) Comparison of Benefits for Downstream Features

(Average Annual Dollars in Thousands)

Alternative Number	Future	Water Treatment Damages		Flow Related Damages				Irrigation	Overall Benefits[1]
		Municipal	Industrial	Ag-Crop	Ag-Other	Urban	Transportation		
M1-1	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2	
	With Project	$22	$12	$499	$179	$12,099	$1,909	$36	
	Total Benefits	-$22	-$12	-$6	$0	-$2	$0	-$34	-$76
M1-2	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2	
	With Project	$3,343	$56	$530	$182	$12,125	$1,930	$365	
	Total Benefits	-$3,343	-$56	-$37	-$3	-$28	-$21	-$363	-$3,851
M1-3b	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2	
	With Project	$21	$12	$499	$179	$12,099	$1,909	$36	
	Total Benefits	-$21	-$12	-$5	$0	-$2	$0	-$34	-$75
M1-5	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2	
	With Project	$31	$19	$516	$180	$12,114	$1,914	$37	
	Total Benefits	-$31	-$19	-$23	-$1	-$17	-$6	-$35	-$132
M1-6	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2	
	With Project	$2,764	$43	$534	$182	$12,125	$1,936	$399	
	Total Benefits	-$2,764	-$43	-$41	-$3	-$28	-$27	-$397	-$3,303
M1-7	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2	
	With Project	$11	$6	$503	$179	$12,097	$1,908	$3	
	Total Benefits	-$11	-$6	-$10	$0	$0	$0	-$1	-$28
M1-8	Without Project	$0	$0	$493	$179	$12,097	$1,908	$2	
	With Project	$9	$5	$501	$180	$12,097	$1,920	$3	
	Total Benefits	-$9	-$5	-$8	-$1	$0	-$12	-$1	-$36

[1]This value includes only damages prevented by the project. Capital costs associated with outlet projects are considered project costs, and are therefore counted as an up-front cost rather than a damage.

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits.

Economic Analysis of Devils Lake Alternatives

Table M2-1

Moderate Future 2 Scenario (1455 Peak Lake Level) Cost and Benefit Comparison

(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Devils Lake Basin Only				Including Downstream Impacts			
		Ann. Costs	Ann. Bens	Net Bens	BCR	Ann. Costs	Ann. Bens	Net Bens	BCR
M2-1	West Bay 300 cfs Constrained Outlet	$ 4,425	$5,564	$1,139	1.26	$ 5,936	$5,489	-$447	0.92
M2-2	West Bay 480 cfs Unconstrained Outlet	$ 7,289	$13,167	$5,878	1.81	$ 11,721	$8,910	-$2,810	0.76
M2-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$ 8,734	$10,112	$1,378	1.16	$ 10,246	$10,043	-$202	0.98
M2-5	Pelican Lake 1 - 300 cfs Constrained Outlet	$ 6,494	$11,196	$4,702	1.72	$ 8,005	$11,081	$3,076	1.38
M2-6	Pelican Lake 1 - 480 cfs Constrained Outlet	$ 9,913	$13,498	$3,585	1.36	$ 14,351	$10,504	-$3,847	0.73
M2-7	Pelican Lake 2 - 480 cfs Constrained Outlet	$ 13,990	$10,504	-$3,486	0.75	$ 15,501	$10,410	-$5,091	0.67
M2-8	Pelican Lake 3 - 480 cfs Constrained Outlet	$ 20,442	$13,409	-$7,033	0.66	$ 21,954	$13,314	-$8,640	0.61

N.A. - The downstream impacts for the stochastic scenario were computed based on the weighted averages of the sensitivity scenarios.
Not all of the alternatives were analyzed in the sensitivity analyses, therefore the downstream impacts are not computable.

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits.

Economic Analysis of Devils Lake Alternatives

Table M2-2

Moderate Future 2 Scenario (1455 Peak Lake Level) Comparison of Benefits for Features Adjacent to Devils Lake

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Set of Feature Strategy Costs	Benefits To Adjacent Lake Features
		Without-Project	$2,015	$17,635	
		With-Project	$1,736	$12,349	
M2-1	West Bay 300 cfs Constrained Outlet	Total Benefits	$279	$5,285	$5,564
		Without-Project	$2,015	$17,635	
		With-Project	$963	$5,523	
M2-2	West Bay 480 cfs Unconstrained Outlet	Total Benefits	$1,052	$12,112	$13,164
		Without-Project	$2,015	$17,635	
		With-Project	$1,418	$8,120	
M2-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	Total Benefits	$597	$9,515	$10,112
		Without-Project	$2,015	$17,635	
		With-Project	$1,208	$7,246	
M2-5	Pelican Lake 300 cfs Constrained Outlet	Total Benefits	$807	$10,388	$11,195
		Without-Project	$2,015	$17,635	
		With-Project	$963	$5,192	
M2-6	Pelican Lake 480 cfs Unconstrained Outlet	Total Benefits	$1,052	$12,443	$13,495
		Without-Project	$2,015	$17,635	
		With-Project	$1,313	$7,833	
M2-7	Pelican Lake 2	Total Benefits	$702	$9,802	$10,503
		Without-Project	$2,015	$17,635	
		With-Project	$757	$5,484	
M2-8	Pelican Lake 3	Total Benefits	$1,258	$12,151	$13,408

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits.

Economic Analysis of Devils Lake Alternatives

Table M2-3

Moderate Future 2 Scenario (1455 Peak Lake Level) Comparison of Benefits for Downstream Features

(Average Annual Dollars in Thousands)

Alternative Number	Future	Water Treatment Damages Municipal	Industrial	Flow Related Damages Ag-Crop	Ag-Other	Urban	Transportation	Irrigation	Overall [1] Benefits
M2-1	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1	
	With Project	$24	$14	$430	$147	$7,293	$1,804	$18	
	Total Benefits	-$24	-$14	-$11	-$1	-$5	-$2	-$17	-$74
M2-2	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1	
	With Project	$3,816	$73	$468	$148	$7,310	$1,806	$291	
	Total Benefits	-$3,816	-$73	-$49	-$1	-$23	-$4	-$290	-$4,256
M2-3b	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1	
	With Project	$22	$12	$429	$147	$7,292	$1,804	$18	
	Total Benefits	-$22	-$12	-$10	-$1	-$5	-$2	-$17	-$69
M2-5	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1	
	With Project	$33	$23	$443	$147	$7,301	$1,805	$19	
	Total Benefits	-$33	-$23	-$24	-$1	-$13	-$3	-$18	-$115
M2-6	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1	
	With Project	$2,739	$54	$468	$148	$7,310	$1,806	$125	
	Total Benefits	-$2,739	-$54	-$49	-$1	-$23	-$4	-$124	-$2,993
M2-7	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1	
	With Project	$15	$11	$458	$148	$7,310	$1,806	$1	
	Total Benefits	-$15	-$11	-$39	-$2	-$23	-$4	$0	-$93
M2-8	Without Project	$0	$0	$419	$146	$7,288	$1,802	$1	
	With Project	$16	$12	$458	$149	$7,310	$1,805	$0	
	Total Benefits	-$16	-$12	-$39	-$3	-$23	-$3	$1	-$94

[1]This value includes only damages prevented by the project. Capital costs associated with outlet projects are considered project costs, and are therefore counted as an up-front cost rather than a damage.

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits.

Economic Analysis of Devils Lake Alternatives
Table DR-1

Dry Future Scenario Cost and Benefit Comparison
(costs and benefits in thousands of dollars)

Alternative Number	Description of Alternative	Devils Lake Basin Only				Including Downstream Impacts			
		Ann. Costs	Ann. Bens	Net Bens	BCR	Ann. Costs	Ann. Bens	Net Bens	BCR
DR-1	West Bay 300 cfs Constrained Outlet	$4,285	$0	-$4,284	0.00	$ 5,796	-$212	-$6,008	-0.04
DR-2	West Bay 480 cfs Unconstrained Outlet	$6,793	$0	-$6,792	0.00	$ 10,821	-$2,791	-$13,612	-0.26
DR-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	$6,923	$2,754	-$4,169	0.40	$ 8,435	$2,545	-$5,890	0.30
DR-5	Pelican Lake 1 - 300 cfs Constrained Outlet	$6,237	$331	-$5,905	0.05	$ 7,748	$91	-$7,657	0.01
DR-6	Pelican Lake 1 - 480 cfs Constrained Outlet	$9,418	$331	-$9,087	0.04	$ 13,420	-$1,295	-$14,715	-0.10
DR-7	Pelican 2 - 480 cfs Constrained Outlet	$12,893	$8	-$12,885	0.00	$ 14,405	-$198	-$14,603	-0.01
DR-8	Pelican 3 - 480 cfs Constrained Outlet	$18,585	$311	-$18,274	0.02	$ 20,097	$120	-$19,977	0.01

N.A. - The downstream impacts for the stochastic scenario were computed based on the weighted averages of the sensitivity scenarios. Not all of the alternatives were analyzed in the sensitivity analyses, therefore the downstream impacts are not computable.

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits.

Economic Analysis of Devils Lake Alternatives

Table DR-2

Dry Future Scenario Comparison of Benefits for Features Adjacent to Devils Lake

(Average Annual Dollars in Thousands)

Alternative Number	Description of Alternative	Future	Remaining Feature Damages	Set of Feature Strategy Costs	Benefits To Adjacent Lake Features
		Without-Project	$1,048	$5,542	
		With-Project	$1,048	$5,542	
DR-1	West Bay 300 cfs Constrained Outlet	Total Benefits	$0	$0	$0
		Without-Project	$1,048	$5,542	
		With-Project	$1,048	$5,542	
DR-2	West Bay 480 cfs Unconstrained Outlet	Total Benefits	$0	$0	$0
		Without-Project	$1,048	$5,542	
		With-Project	$375	$3,461	
DR-3b	Combination 2-West Bay 300 cfs Constrained Outlet, Upper Basin Management, and Expanded Infrastructure Measures	Total Benefits	$673	$2,081	$2,754
		Without-Project	$1,048	$5,542	
		With-Project	$1,048	$5,211	
DR-5	Pelican Lake 300 cfs Constrained Outlet	Total Benefits	$0	$331	$331
		Without-Project	$1,048	$5,542	
		With-Project	$1,048	$5,211	
DR-6	Pelican Lake 480 cfs Unconstrained Outlet	Total Benefits	$0	$331	$331
		Without-Project	$1,048	$5,542	
		With-Project	$1,041	$5,542	
DR-7	Pelican Lake 2	Total Benefits	$7	$0	$7
		Without-Project	$1,048	$5,542	
		With-Project	$778	$5,501	
DR-8	Pelican Lake 3	Total Benefits	$270	$41	$311

Note: These computations assume that the set of Most Likely Action strategies are conducted for all features adjacent to Devils Lake (under both with- and without-project conditions). The costs and damages for the Maximum Infrastructure Protection alternatives without-project conditions assume the features are not protected or are abandoned.

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits.

Economic Analysis of Devils Lake Alternatives

Table DR-3

Dry Future Scenario (1448 Peak Lake Level) Comparison of Benefits for Downstream Features

(Average Annual Dollars in Thousands)

Alternative Number	Future	Water Treatment Damages		Flow Related Damages				Irrigation	Overall Benefits1
		Municipal	Industrial	Ag-Crop	Ag-Other	Urban	Transportation		
DR-1	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6	
	With Project	$12	$7	$384	$136	$6,457	$1,628	$23	
	Total Benefits	-$12	-$7	-$8	-$1	-$165	-$2	-$16	-$212
DR-2	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6	
	With Project	$2,328	$38	$391	$137	$6,506	$1,635	$192	
	Total Benefits	-$2,328	-$38	-$16	-$2	-$214	-$9	-$185	-$2,792
DR-3b	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6	
	With Project	$12	$7	$384	$136	$6,456	$1,628	$23	
	Total Benefits	-$12	-$7	-$8	-$1	-$164	-$2	-$16	-$210
DR-5	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6	
	With Project	$17	$11	$394	$136	$6,468	$1,629	$20	
	Total Benefits	-$17	-$11	-$18	-$1	-$176	-$3	-$14	-$240
DR-6	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6	
	With Project	$1,316	$21	$391	$137	$6,506	$1,635	$55	
	Total Benefits	-$1,316	-$21	-$15	-$2	-$214	-$9	-$49	$0
DR-7	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6	
	With Project	$5	$3	$391	$136	$6,469	$1,630	$6	
	Total Benefits	-$5	-$3	-$15	-$1	-$177	-$4	$0	-$205
DR-8	Without Project	$0	$0	$376	$135	$6,292	$1,626	$6	
	With Project	$5	$4	$386	$136	$6,461	$1,629	$6	
	Total Benefits	-$5	-$4	-$11	-$1	-$169	-$3	$0	-$192

[1] This value includes only damages prevented by the project. Capital costs associated with outlet projects are considered project costs, and are therefore counted as an up-front cost rather than a damage.

Note: Costs and benefits expressed on an "average annual" basis for this scenario only and assume that this scenario has a 100-percent probability of occurrence. This differs from standard definition of "average annual" which assigns the probabilities of a range of scenarios occurring as weights in calculating expected value of damages and benefits.